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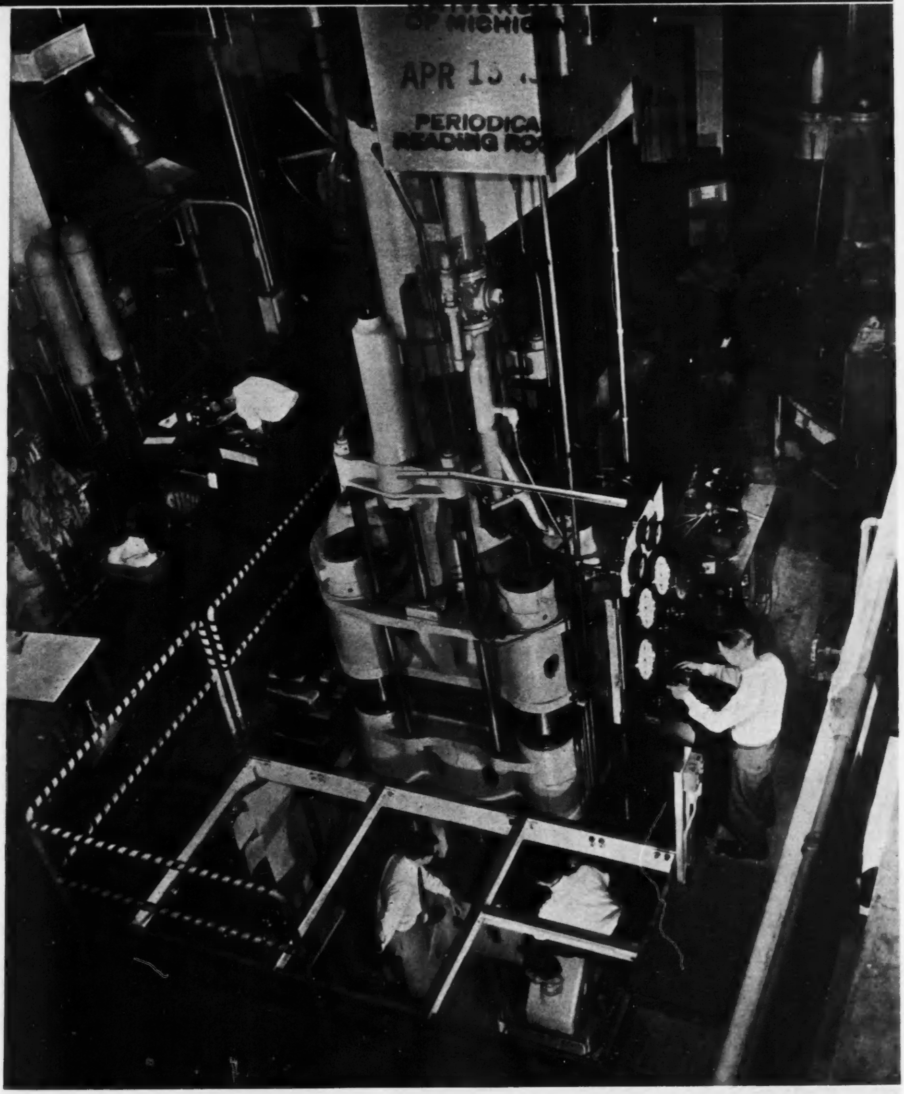

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THE MAGAZINE OF SCIENTIFIC PROGRESS

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THE PROGRESS OF SCIENCE

SCIENCE TEACHERS AND THE NEW BURNHAM PROPOSALS

The salaries of many science and mathematics masters will be increased now that the Minister of Education has approved the proposals of the Burnham Committee announced at the end of February.

It was in December 1954 that the Minister asked the committee to look at the position of all teachers engaged in more responsible or advanced work, and this request was prompted, of course, by the very serious shortage of science masters that has been affecting many schools over a long period. The Burnham Committee recommended a scheme of specific payments to be given as special allowances to teachers doing advanced work in secondary schools, and the Minister has accepted these recommendations *in toto*.

Under the 1951 and 1954 Burnham Awards, Local Education Authorities have been permitted to make special allowances to teachers who hold posts of special responsibility in primary and secondary schools, the minimum total to be paid in each school being determined by a "points" scheme based on ages and numbers of pupils.

The new scheme lays down special allowances ranging from £75 to £175 for all men who teach five or more periods of advanced work per week, advanced work being defined as work above the Ordinary Level in the G.C.E. For men who teach advanced work and who are in charge of their subjects the recommended allowances are between £100 and £200 in small schools, and between £200 and £350 in large schools. The exclusion of women teachers from the new recommendations can only mean that their whole case is now subject to a complete review following the recent decision on equal pay.

The new allowances are to be welcomed as a first step towards the aim of attracting specialists into advanced work. Quite apart from the counter-attractions of the scientific careers offered in industry, the Civil Service and the universities, young specialists have hitherto often been attracted away from science teaching in grammar schools by the better prospects of allowances and headships in modern and primary schools, and students thinking of teaching have seen the advantage of a short course in a training college rather than a long course leading to a university degree and specialist work. The new recommendations will be important in correcting these trends and in attracting young scientists not merely into teaching but into the advanced level work where they are most needed.

If the scheme is properly applied, then we can look forward to the prospect that the grammar schools, which in particular stand to benefit, will be enabled to recruit the scientists they have lacked for several years. The smaller grammar schools, which have appeared less attractive to recruits than the large secondary modern schools, ought to profit greatly under the new scheme, while in the larger grammar schools those men who profit little financially cannot be unaffected by the increased prestige which is at last given to advanced work.

We understand that the scheme is mandatory to the extent that the Local Education Authorities will be bound to pay the minimum figure in each range. There will remain, however, considerable discretion for the L.E.A.'s within each range. Past experience justifies the fears that any niggardly authorities will be free to spoil this new scheme, just as the intentions behind the last Burnham Award were not fulfilled in some areas where only the minimum Special Responsibility Allowances were paid. Local parsimony cannot be justified in face of the serious national shortage of science teachers, but this shortage may require nothing less than a national remedy. One suggestion worthy of further consideration is that the whole cost of these new allowances should be met by the Treasury.

We would draw attention to the fact that the proposals were forthcoming only after the Minister had asked the Burnham Committee to consider these matters. The Minister deserves congratulations for his initiative. On the other hand, there has been a critical

shortage of science and mathematics teachers for several years, but this did not lead the Burnham Committee to take the initiative and come to a firm decision. That decision was forthcoming only after the Minister had applied polite pressure. This suggests that there is a need for an early review of the Committee's constitution and machinery. For the future it is to be hoped that, whatever changes are made from time to time in teachers' salaries, adequate differentials will always be laid down for advanced work, and not merely for qualifications and responsibility.

One final point should be mentioned. The scheme will not succeed in bringing more young science graduates into the schools if starting salaries and career prospects elsewhere are relatively much more attractive. In this context industry is obviously a major competitor, and it is noteworthy that on the day the Minister announced his acceptance of the new Burnham scheme the Federation of British Industries circularised all member firms asking them to exercise restraint in bidding against the schools for science graduates. The intention behind the F.B.I.'s circular was altogether admirable, but only time will show whether it will have the desired effect on individual firms that need more scientific staff.

A NEW INDUSTRIAL REVOLUTION

The Government White Paper entitled "A Programme of Nuclear Power" (Cmd. 9389, H.M. Stationery Office, 9*d*.) is likely to prove an historic document. Up till its appearance in the middle of February much had been written and said about *experimental* units for the production of nuclear power. Obviously the nuclear engineers responsible for the design of the units for Calder Hall and Dounreay had been making great progress, but to most people the practical plans for commercial nuclear power production on a considerable scale that were announced in the White Paper came as a considerable and pleasant surprise. It is now evident that our nuclear engineers are forcing the pace in the field of commercial power production, and are now engaged in the detailed designs of atomic power stations which will give Britain a flying start in a new industrial era.

The programme is certainly an ambitious one, but clearly it is one that the experts expect to be able to fulfil. Twelve atomic power stations are scheduled to be built in the period 1955–65.

The first two stations, for which the Calder Hall station is to be regarded as the prototype, will begin building about the middle of 1957, and should be operating in 1960 or 1961. These will each have two reactors, which will be gas-cooled and graphite-moderated. In 1958–9 building will start on two other similar stations of improved design. Each of the eight reactors in these early stations would have a net output of electricity of 50–100 megawatts so that the total output from the four stations, which should all be in operation by 1963, would be somewhere between 400 and 800 megawatts.

The second group of power stations would start building in 1960 and all should be completed by 1965, and between them they should have a total capacity of well over 1000 megawatts. Probably four out of these eight stations will be of the liquid-cooled type.

At the end of the ten-year period, therefore, Britain should have twelve nuclear power stations with a capacity of 1500–2000 megawatts. That is equivalent to power production by coal-fired power stations using something of the order of 6 million tons a year.

The cost of the programme to be completed in 1965 is estimated at about £300 million.

The White Paper says a little about the cost of nuclear fuel for these power stations. The initial charge of fabricated uranium fuel elements for one of the early types of station similar to Calder Hall "may amount to about £5 million". A new charge costing the same amount will be needed every three to five years. The document also states that it is expected that it will prove possible to extract as much as 3000 megawatt-days of heat from every ton of fuel. This is the equivalent of the heat from 10,000 tons of coal. It points out that no practical experience has yet been gained of this level of irradiation at high temperatures, and the metallurgical behaviour of the fuel elements is uncertain. But it adds that there are many lines of development which should overcome such metallurgical defects as may appear.

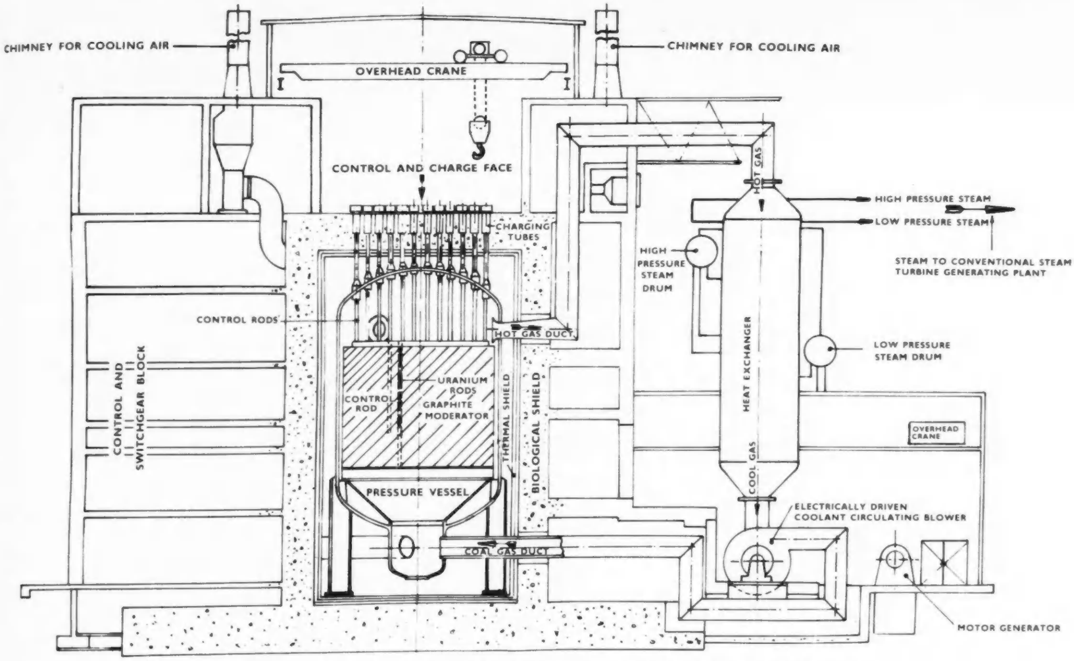
The uranium fuel elements will in course of time come to contain a substantial amount of plutonium, and this will be a valuable by-product of any power pile. When the uranium slugs are removed and replaced by a new charge of nuclear fuel, the plutonium will be extracted, and can be used in its turn as concentrated fissile material in other piles. More and more plutonium will become available as new power stations get into their stride, and eventually it may become abundant enough to use as a substitute for natural uranium. The White Paper does not envisage this happening for fifteen to twenty years.

The estimated cost of electricity generated in these nuclear power stations is given as about 0·6*d*., as compared with the average cost of 0·72*d*. for electricity generated in Britain in 1952.

In his speech introducing the White Paper, the Minister of Fuel and Power (Mr. Geoffrey Lloyd) looked a little ahead beyond 1965, and said that by 1975 Britain might be producing nuclear power equivalent in quantity to the power from about 40 million tons of coal. These figures gain in significance if one puts them alongside the best estimates of the amount of coal our power stations would be using in the absence of any contribution from nuclear power; by 1965 the electricity stations would require about 65 million tons of coal, and probably 100 million tons a year in the 1970's.

Mr. Geoffrey Lloyd very rightly stressed that no one should get the idea that coal will cease to matter now that atomic energy is on the way. As he said, coal-mining will continue to be the backbone industry of Britain for our lifetime and our children's lifetime.

The first benefit which the implementation of this programme will bring is more power for our expanding factories. The second benefit, said Mr. Lloyd, will be



Diagrammatic section of Calder Hall power reactor. This is the prototype for the reactors to be installed in the first of the new power stations announced by the Government.

the development of a new export trade, with Britain supplying complete nuclear power stations to other countries.

The carrying out of the programme will depend on a three-way partnership. The Atomic Energy Authority will continue their pioneering work in the research and development field. The new techniques that they will bring to the pitch of commercial application will be handed on to the Electricity Authorities and to British electrical firms. The latter will build the power stations ordered by such public electricity undertakings as the British Electricity Authority, which will own and operate the revolutionary new stations.

Mr. Lloyd did not name any of the big electrical firms that will be concerned in the practical realisation of these plans, but *The Financial Times* has reported that these include General Electric, English Electric and Associated Electrical Industries (where B.T.H. and Metro-Vickers are especially concerned). Other companies reported by that newspaper to be concerned in the development of these power station project studies include Head Wrightson Processes, which is working on heat exchanger problems; John Thompson, working on steam plant development; A. Parsons & Co., the turbo-generator and alternator manufacturers; and Ewbank & Partners, the consulting engineers.

Experts from these firms are already well acquainted with the basic facts of nuclear engineering, having attended courses organised at the Reactor Training School at Harwell, where the first students were received in September 1954. B.E.A. engineers are also receiving basic training in this new branch of technology.

In February 1946, when Sir Christopher Hinton was given the task of laying the foundations of an atomic industry, Britain had no engineers with any knowledge of atomic energy work. The country has indeed come a long way since then, as Mr. Lloyd said. Britain is the first country in the world to announce plans for a chain of nuclear power stations. The Americans now admit that our efforts to produce nuclear power for industrial power have outpaced theirs, and the scientists and engineers responsible for the fact that Britain is in the lead are entitled to the nation's gratitude. When the war ended Britain had a great deal of leeway to make up. In 1945 we did not have one atomic pile in operation, whereas there were several large atomic piles working in America. It was in fact not until 1947 that Harwell's first pile started ticking over, and that was essentially only a research tool. Our development work has kept pace with our researches, and it is important that in the next few years our record of achievement in both spheres shall be maintained so that the country retains its lead in the Age of Atomic Power which is now so close to us.

SCIENCE AND BRITISH INDUSTRY

In recent years the views expressed about scientific and technological matters in Parliament have been much better informed than they used to be. This change is an

indication of the beneficial influence of the Parliamentary and Scientific Committee, an organisation which includes members of both Houses of Parliament and also representatives of many scientific bodies. This committee is bound to gain in influence, as the result of the change in its rules which makes it possible for the great engineering institutions—Civil, Mechanical and Electrical—to be represented on the committee.

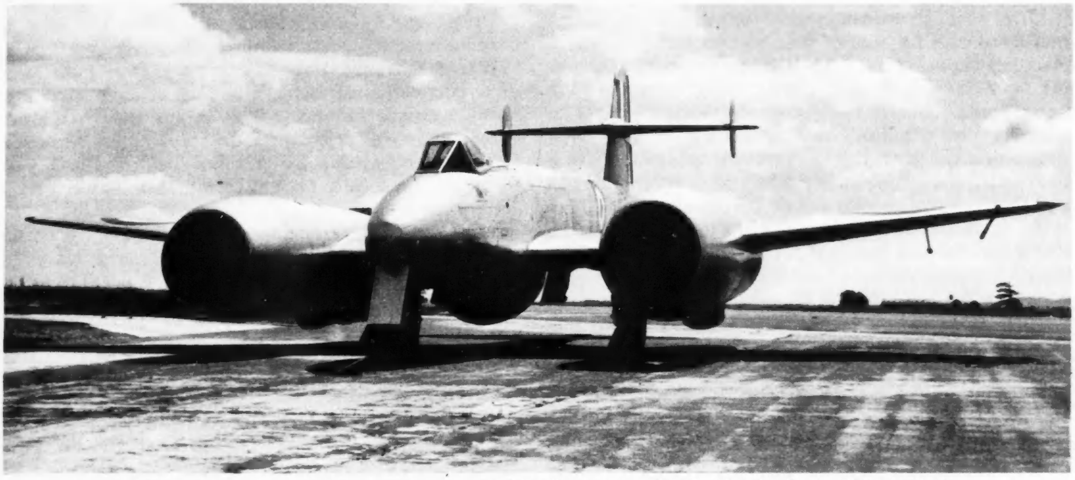
A succession of first-class speakers has addressed this committee's annual luncheons. This year's speech was prepared by Lord Salisbury, the Lord President of the Council, but was read in his absence by the Minister of Supply. It proved to be as provocative and forthright as any that have been heard at this function. The particular issue which Lord Salisbury raised was the adequacy of the scientific effort in British industry. This is a very important consideration when one realises that over the years there have been radical changes in the whole structure of British industry, and one factor causing these changes is the exploitation of new inventions firmly based on scientific research. These radical changes are also bound up with the changes that have occured in overseas demand for British goods, and the present trend is for the demand for our exports to shift more and more to specialised products where quality and special skills play a main part. The scientific content of such industries is bound to be high.

Having established this context, Lord Salisbury considered how strong Britain is scientifically. He maintained that in the realm of pure science our achievements compare very favourably with those of other countries, and most people would agree with that assessment. But he did not take the same view of British applied science. In fact he went so far as to say that "it is unfortunately true that with some notable exceptions we tend to lag behind some of our competitors in the speed with which we apply scientific knowledge". He implied that the gap between pure research and its application was one of our major problems, and he conveyed the impression that where productivity in a particular industry lagged behind productivity elsewhere then that was due to insufficient scientific effort. Support for this view can be found in the reports of the British Productivity teams which have visited the U.S.A. since the war. He said that these teams found, in general, that there were few technical innovations in the States which were not known in Britain, but that the latest techniques were in much more general use in the U.S.A. than here. That indicates clearly that it is necessary, by some means or other, to modernise the outlook and raise the efficiency of our technically less progressive firms. The DSIR is doing what it can. The various research stations themselves publish a great quantity of literature covering a wide variety of subjects, and the results of research undertaken by these stations are also expounded in scientific journals, in lectures and in the annual reports both of the research stations and of the DSIR itself. There are, moreover, conferences, lectures and facilities for enabling nominees of firms to make themselves acquainted with the work of the various research laboratories. And, in addition to the work undertaken by the DSIR's own stations, there is all the valuable work which is being done by the Research Associations. Lord Salisbury went on to stress the fact that half of the manufacturing labour force in the country is in firms employing 250 or less, where in a large proportion of cases there are no arrangements at all for keeping in touch with the results of modern research and technical developments. The permeation of industry by science is not a one-way process, and it is difficult, if not impossible, to bring the benefits of science to those who do not stretch out a hand.

Lord Salisbury suggested that probably the most effective way of closing the present disturbing hiatus between science and business will be found in making much fuller use of suitably trained scientists in responsible positions in industry. The practice is widespread in the United States and in many leading firms in this country. It ensures that those responsible for making decisions are competent to appreciate the technological details. It also means that those in authority are able to appreciate more quickly developments of research discoveries both in the firm itself and in the world outside. A further advantage is that the scientists engaged on research are brought into closer touch with the other sides of the business. "It is not much use scientists inventing magnificent machines which no one wants; nor is it much good producing things which are wanted, but at a wrong price. Some economists claim that scientists tend to be out of touch with market conditions and to be over-optimistic about the speed at which their inventions can be developed. Whether or not there is any truth in this I don't know. But I am sure that it must be helpful to both sides for scientists to be in responsible positions, in daily touch with the problems of administration and salesmanship", said Lord Salisbury.

Today British industry needs more trained scientists at every level, and here the country is faced with a considerable shortage of scientific manpower. The Government, said Lord Salisbury, is anxious to do everything it can to increase the supply, though he said nothing about the necessity of ensuring an adequate supply of science teachers without which it is virtually impossible to maintain, let alone increase, the supply of scientists in the future. It has been said with justification that research has been over-glamorised at the expense of other kinds of scientific activity. Lord Salisbury was at pains to redress the balance. To quote his exact words: "Parents and schools must play their part too in influencing more of the bright boys to take up applied science and engineering as a career. At present, the attractions of 'pure' science to our best brains is exceedingly strong—as it should be. But that is no reason why engineering and technology should be regarded as a kind of 'Cinderella'. The application of science is just as important to the world as science itself, and we must recognise that fact, if our technologists and our engineers are to continue—as in the past—to set an example to the world."

The introduction of more science into industry is not always a smooth process, and there are many employers



The first British aircraft to be equipped with a jet-deflection unit enabling it to land and take off in confined spaces. The deflected ends of the jet pipes can be seen protruding from the underside of the engine cowling.

and workers who resist the idea that more science could be introduced into their particular industry or particular factory with advantage. Lord Salisbury had something to say on this problem and on the importance of the human factor in industry. There is, he said, a great innate respect for tradition—a natural conservatism—in Britain, which has its merits. But this must not be allowed to hobble us in the vital task of keeping our industry competitive with our less technologically conservative competitors abroad. Lord Salisbury continued: "We must induce the more old-fashioned employers to take an up-to-date view; and we must persuade the rank and file of the Trade Unions—as many of their wisest leaders already recognise—that innovation can be a 'good thing', and may be vitally necessary as a means of raising or even maintaining the workers' standard of living. But before this is possible, we shall have to establish a firmer basis of understanding between management and workers than exists in many firms today. Much is being done about this, and I am glad that the DSIR and the Medical Research Council, through their committees on the Human Factor in Industry, are playing a prominent part in this work. I hope that more still will be done in the future: for it is essential that the new spirit should be inculcated by every possible means if we are to achieve the higher productivity on which our future depends."

Lord Salisbury concluded by saying that he was not asking his audience to be prophets of gloom. He felt the future offered wonderful possibilities, but these could only be realised if people took a clear-sighted, objective and informed view of what we must do—particularly in the industrial and technological fields—if we are to retain, and enhance, the technological predominance which has stood this country in such good stead in the past, and on which her prosperity and maybe her very existence assuredly depend in the years that lie ahead.

JET DEFLECTION: A STEP TOWARDS VERTICAL TAKE-OFF

An important new jet-engine development is now under test at the Royal Aircraft Establishment, Farnborough. This is a jet-deflection system by which the thrust can be directed downwards to the ground so as to lift an aeroplane off the ground more easily than with the usual horizontal thrust.

The present Farnborough experiments, using a Gloster Meteor fighter, are aimed immediately at shortening both take-off and landing distances, and reducing landing speeds—a most important objective. They may be regarded as representing another step towards vertical take-off aeroplanes. Power output of aero engines goes on increasing, and vertical take-off will be possible when the thrust of an aeroplane's engines is greater than its total weight.

Scientists of the National Gas Turbine Establishment, Farnborough, headed by Dr. Hayne Constant, devised the jet-deflection system. Installation of the deflector units to the Meteor's two Rolls-Royce Nene engines (the standard Meteor fighter has less powerful Derwents) was carried out for the Ministry of Supply by the Westland Aircraft Company at Yeovil, and the first flight was made by a Westland test pilot. These tests have gone on in secret for the best part of a year. Only now has the existence of Britain's first jet-deflection aeroplane been made known, and details of the way in which the deflection is achieved are still secret.

Each of the engines has two jet pipes—the usual one, and the deflector pipe set at an angle of 60° downward half-way along the engine nacelle. For taking-off, the pilot uses the downward thrust, and when the plane is airborne he switches over to the main jet. On approaching to land, use of the downward thrust, by reason of the added "lift" it gives, lowers the aeroplane's stalling speed and allows a very much gentler landing. If, when coming in, the pilot should be faced with a

sudden need to climb again the downward thrust quickly checks the rate of descent and drives the aeroplane upwards. All round, the new device will give future aircraft much greater ease of control, with a resultant increase in safety.

It has been found that the Meteor fitted with the new device can approach the runway at a speed 20% lower than that which is necessary when using the normal jet pipes. The experimental Meteor is reported to be able to keep flying at 20 miles an hour less than the minimum flying speed of the standard Meteor.

The designers say that with the added "boost" helping an aeroplane off the ground more quickly it will be possible to build smaller aircraft for the same take-off weight. This would mean an important saving in structure weight while increasing the load the aeroplane could carry. Thus, if the increased load represented fuel the aircraft's flying range would be greater. The new development is of great importance to the interceptor fighter, for it will enable it to save time in getting into the air and increase its endurance.

THE HYDROGEN BOMB AND BRITISH DEFENCE

The official announcement that Britain is capable of making thermonuclear weapons—made in the White Paper on Defence—implies a very considerable compliment to the research team led by Sir William Penney at the Atomic Weapons Research Establishment, near Aldermaston in Berkshire. Those who have read the transcript of the Oppenheimer hearings will know that the production of an operational thermonuclear weapon proved to be far more formidable than many U.S. scientists had anticipated. The idea of an H-bomb was conceived long before Hiroshima, but it was not until Dr. Edward Teller hit upon a brilliantly original and quite unexpected idea that any substantial headway could be made. The British thermonuclear weapon must also be based on a brilliant and original idea, for it is quite certain that the Government has had no help from the Americans in this connexion.

Ten months ago the *Daily Express* Science Correspondent asserted that the Aldermaston team was working on a thermonuclear weapon of a novel kind, and claimed that this device stemmed directly from the second of the two atomic explosions staged at Woomera in October 1953. We have other good evidence for believing that something very exceptional was accomplished during that test and it is not unreasonable to suppose—since there have been no further atomic tests—that the British scientists' certainty of their ability to produce thermonuclear weapons is linked with that explosion.

The future programme of defence research and development as outlined in the White Paper shows that the bulk of the effort and expenditure is to be devoted to atomic (including thermonuclear) developments and guided missiles.

The Government hopes to prevent war by building up a deterrent stock of H-bombs and the means of delivering them. If our skies have to be defended, manned fighters and guided missiles will share the burden in the foreseeable future.

It is clear from the White Paper and from Parliamentary statements that the development of the guided anti-aircraft missile has proved to be a far more difficult project than was first expected. The amount of money, effort and talent devoted to this task in the last seven years is fantastically high. More than a hundred firms have been working on missile development, but as yet we seem to have no operational weapon coming off the production line. This is not so surprising when the requirements of the missiles are appreciated. They must be effective at heights up to at least 60,000 feet, and because of the speed with which a modern bomber approaches its target they must have ranges of at least thirty miles. The guidance problems against manned bombers which can take evasive action are enormous. The device has to be immune from easy jamming by an enemy plane. In addition it has to be simple enough in service to be operated by troops.

The White Paper shows that much progress is being made with guided missiles, however, for firing trials of many prototypes are taking place at the rocket range at Woomera, Australia. Whether these weapons will ever be effective enough before a further development on the offensive side renders them obsolete is debatable. The White Paper makes it clear that the bomber will soon be supplemented and may eventually be supplanted by the ballistic rocket—a bombarding weapon of the V-2 type which is launched on a pre-set course, and being unguided is also unjammable.

Ballistic rockets, which may eventually have intercontinental ranges, will travel at such heights and such speeds that interception by guided missiles is not likely to be possible. Admittedly they are inaccurate, but when they are fitted with atomic or thermonuclear warheads—and the White Paper points out that this will be possible—inaccuracy of several miles will be of little consequence.

The White Paper consolingly states that methods of defence against this form of attack are being considered. No scientists we have met hold out any prospect that this search will be successful.

It seems abundantly clear that no Civil Defence measures against thermonuclear attack in any form are likely to be very effective. Any British plans to cope with such disasters are to await fuller study of the effects of the massive fall-out of radioactive particles from ground-burst H-bombs. (Incidentally it is only in the past few weeks that any hint has been given to the public of the scale of this fall-out; an American spokesman has stated that an area of the order of 10,000 square miles would be dangerously affected by the spreading of radioactive particles from such an explosion.)

There is no mention of chemical or biological warfare in the White Paper, and whilst research on these projects continues they have clearly been greatly reduced in priority since the emergence of the thermonuclear bomb.

To sum up, the White Paper confirms the growing opinion that offence has left defence irretrievably far

behind. There seems to be no chance of a worth-while victory for either side in a future conflict fought with thermonuclear weapons—and the Government has made it clear that the NATO powers are irrevocably committed to dependence on these weapons.

We can only trust, therefore, that the Government is right in its hope that horror weapons have made war profitless.

H-BOMBS AND THE WEATHER

Since the end of the last war more and more people have convinced themselves that the exploding of nuclear weapons has upset the weather, and the poor summer of 1954 was explained as resulting from the atmospheric disturbances caused by the test explosions of hydrogen bombs. Statements by scientists to the newspapers offered no support for this idea, but this did not appear to disturb the convictions of those who had made up their minds that the hydrogen bomb was the source of all the meteorological disappointments. Now a well-argued paper on the subject has been written by Sir Graham Sutton, director of the Meteorological Office, and published in *Nature* (February 19, 1955, pp. 319–21), and this should effectively clear away some of the mistaken ideas which have tended to cloud the controversy about the possible effects of hydrogen bombs on the weather.

Sir Graham begins by challenging the view that last summer was an exceptionally bad summer. The British Climatology Branch of the Meteorological Office has been examining the trend of the British climate since the beginning of this century. In the periods 1922–31 and 1929–38 the summers were warmer than the average for the period 1901–53. We are now apparently in a period in which the trend is towards cooler summers. Summer rainfall seems to be on the increase, and the current trend in summer sunshine is towards lower values. Sir Graham comments that these results suggest (but he stresses that they do not positively demonstrate) that the weather of 1954 continued a general trend that had been indicated for some years past. He adds that "this suggestion cannot be properly examined until future years have produced more observations, but at least it indicates the possibility that cool, wet summers will not be infrequent for some years to come". The *general* character of the current trend would not, of course, be affected if the summer of 1955 turned out to be very warm and dry—as most people hope it will be.

Having conclusively established that the weather record of 1954 fits into the general pattern of a long-term cycle and was not extraordinarily bad, Sir Graham then proceeds to consider the scale of the atmospheric disturbance caused by hydrogen bombs. Very little has been published about the explosive power of such bombs, but Sir Graham takes a U.S. statement indicating that one particular H-bomb explosion was about 600 times more powerful than the Nagasaki bomb, and compares the energy released with the kinetic energy involved in an average cyclonic disturbance. He arrives at a figure of the order of 10^{16} gram-calories for that H-bomb, as against the figure of $3{\cdot}5 \times 10^{16}$ gram-calories for the atmospheric disturbance. He adds this comment: "Thus the energy release in what is thought to have been the most violent explosion to date is equivalent to the addition of one rather small depression to the atmosphere, or to an increase of the kinetic energy of the whole circulation by slightly more than one part in ten thousand, assuming that the whole of the energy released appears as energy of motion. . . . Those who seek support for the theory that the effects of the explosions were felt all over the world in increased cyclonic activity, lasting for many months, are faced with a difficult task. Even in the case of the largest volcanic explosions, any strengthening of the general circulation is not detectable more than six months after the event." (This question of the relative amounts of energy involved was vividly answered by B. J. Mason, the meteorologist of the Imperial College of Science and Technology, in a statement published in *The Times* on February 21, 1955; he said that "a modest thunderstorm releases about as much energy as ten atomic bombs, while that of a hurricane could not be matched by the explosion of several hundreds of hydrogen bombs". Mr. Mason also dealt with the suggestion that because large weather systems, such as depressions, may grow rapidly from small beginnings, the hydrogen bomb might act as a "trigger". This idea, however, arises from a misconception that large regions of the atmosphere are often so delicately balanced that a slight disturbance, applied almost anywhere, would grow rapidly. In fact, natural perturbations are continually being created so that it would be an extraordinary coincidence if a single artificial stimulus were to occur at just the right time and place for it to take precedence.)

There remains to be considered whether the dust from the bomb explosion could have a big and long-lasting effect. Here Sir Graham Sutton starts by looking into the effects of dust from volcanic eruptions. The late W. J. Humphreys in his well-known book *The Physics of the Atmosphere* advanced the hypothesis that volcanic eruptions, by ejecting immense clouds of fine dust into the upper atmosphere, could change the amount of solar radiation reaching the earth's surface and so cause cool, wet weather, and even severe winters. If Humphreys's hypothesis is a sound one, then the climatic record of Britain for the year following the Mt. Pelée eruption of 1902 or the Katmai eruption in Alaska of 1912 should provide evidence that the tremendous volcanic activity had made an impression on the world's weather. Dust from both volcanoes travelled round the world and polluted the upper atmosphere over Europe, but in neither case did observations made in Britain support Humphreys's hypothesis. The next step in Sir Graham's argument is a comparison of the volcanic eruptions with the hydrogen-bomb explosions, and he decides that the amount of dust produced by the latter would be less—and probably many times less—than the amount of debris thrown into the air when Krakatoa erupted. He makes the categorical statement that "so far, there has been no indication of any reduction of solar radiation in the British Isles that can be attributed

to pollution arising from thermonuclear explosions in the Pacific".

The dust from both hydrogen bombs and volcanoes has circled the world, but only the volcanic ash seems to have been abundant enough to affect appreciably the amount of solar radiation reaching the earth. If the dust thrown up by the greatest volcanic eruptions in history has had no observable effect on the climate of the world, then the smaller quantity released by hydrogen-bomb explosions would be even less likely to alter the weather.

Perhaps, however, the fact that the H-bomb dust contains radioactive particles makes a big difference. This point is not ignored by Sir Graham, and he looks at the suggestion that the addition of such dust to the atmosphere might increase rainfall by providing more nuclei for water vapour to condense on. He comes to the conclusion that "it is exceedingly unlikely that radioactive material, whether from a bomb or an atomic pile, can cause any significant increase in rainfall experienced over a large area. In particular, nothing like the classical cloud-chamber process can be envisaged because of the high degree of supersaturation needed."

The World Meteorological Organisation has asked member-nations to collect information about atomic explosions and climatic effects, and Sir Graham says that the data which are collected as a result of that appeal may make some of his arguments out of date. But he comes to the very definite conclusion that "so far the available evidence points to the conclusion that recent thermonuclear trials cannot be held responsible for any world-wide extremes of weather encountered in 1954".

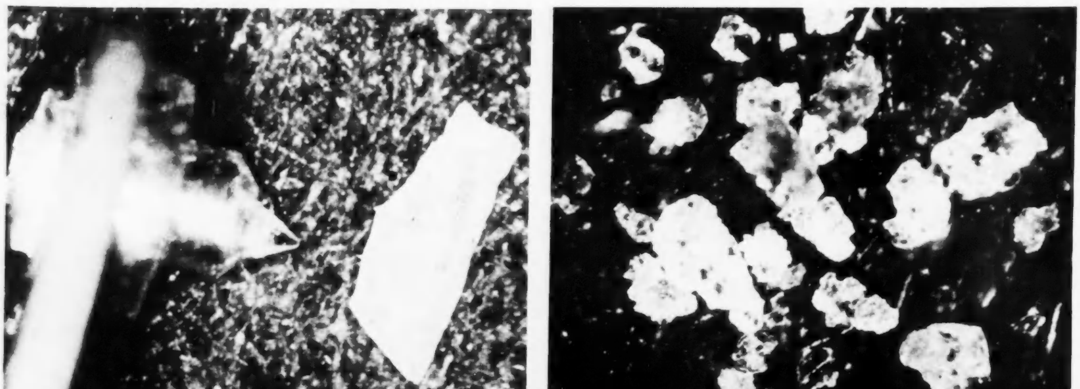
ARTIFICIAL DIAMONDS

The realisation that the diamond was nothing more than an allotropic form of carbon led to several serious attempts in the 19th century to make artificial diamonds. As long ago as 1828 the Frenchman Cagniard de la Tour claimed that he had been successful, but his claim was received with great scepticism. The next major claim in this direction was made by J. B. Hannay in 1880. He worked in Glasgow, and in his experiments he obtained high pressures and high temperatures, comparable to those occurring in the earth when natural diamonds were created, by the following technique. He filled cast-iron tubes with a mixture of bone-oil, paraffin and metallic lithium; then welded them to effect a complete seal, and heated them to redness. The action of the lithium liberated carbon from the paraffin, and a very high pressure was produced inside the tubes. (Indeed several of the inch-thick tubes were shattered by the pressure generated inside them, causing great damage to his laboratory.)

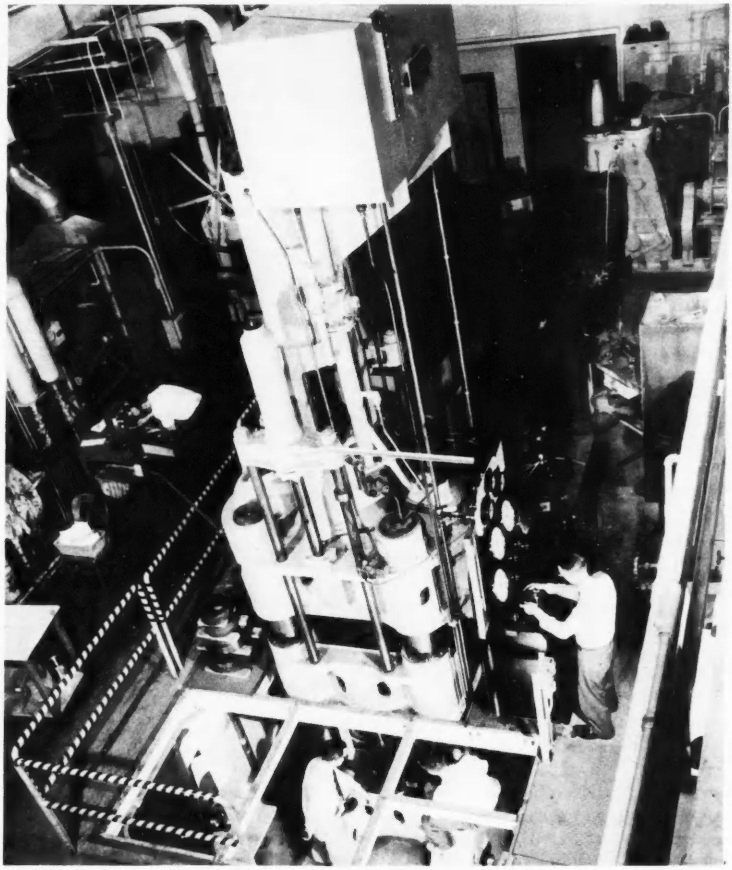
From the charred masses left in the tubes Hannay obtained a total of twelve tiny crystals, and these he believed to be diamonds. The physical properties of these crystals were examined by Nevil Story-Maskelyne and found to match those of natural diamonds. Chemical analyses showed that they had a carbon content of 98%, a piece of evidence strongly supporting Hannay's claim to have prepared artificial diamonds. These crystals were kept in the mineralogy department of the Natural History Museum at South Kensington, and during the recent war Dr. Bannister and Prof. Lonsdale, using X-ray crystallographic method, showed that eleven out of the twelve crystals were definitely diamonds. As DISCOVERY commented in December 1943, "the manufacture of artificial diamonds must be regarded as an accomplished fact".

Another line of research relevant to the latest, and most successful, attempts to produce artificial diamonds has been the high-pressure work of Prof. P. W. Bridgman of Harvard (which was described in DISCOVERY, July 1950, p. 206–8). Pressures of up to 100,000 atmospheres—which is close to 700 tons per square inch—were attained in the course of Bridgman's researches.

In February this year the General Electric Research Laboratory in Schenectady, New York, reported its success in producing diamond crystals of up to one-sixth of a carat. (A carat is a fifth of a gram.) This



LABORATORY-MADE DIAMONDS. (*Left*) The artificial diamond on the right of this photograph is about a sixteenth of an inch long. Compare its size with that of the standard high-fidelity gramophone needle tip. (*Right*) A cluster of typical diamonds made by the Hall-Wentorf process.



THE 1000-TON PRESS WHICH HAS PROVIDED PRESSURES OF UP TO 100,000 ATMOSPHERES FOR THE GENERAL ELECTRIC EXPERIMENTS ON DIAMOND MAKING.

achievement represents one result in a comprehensive research programme for examining various materials subjected to combined high temperature and pressure. The process which yielded the first artificial diamonds made in the General Electric laboratory was devised by Dr. Herbert M. Strong, and depends on the subjection of a carbonaceous compound for many hours to a pressure of some 53,500 atmospheres, or about 800,000 pounds per square inch. The technique is an extension of the work of Dr. H. Tracy Hall, a colleague of his in the G.E. Research Laboratory, who developed a chamber in which it was possible to maintain for the first time temperatures above 5000°F at pressures in excess of 1,500,000 pounds per square inch.

Dr. Strong's own description of what he discovered after opening the pressure chamber is as follows: "While attempting to polish the now solidified matrix, there appeared what we were seeking, a core of superhard matter that refused to wear away under the action of the polishing wheel. With considerable excitement and expectation I removed the crystal from its surroundings, and tried one of its sharp points on sapphire, silicon carbide, and boron carbide. This 'diamond', I could call it now, easily scratched all three."

The pressure involved in Dr. Strong's process is comparable to the "squeeze" which physical scientists have computed for points 240 miles beneath the earth's surface, and is probably of the same order as the pressures associated with the formation of diamonds in nature. Dr. Wentorf of General Electric has developed another successful process involving the use of the same physical apparatus as Dr. Strong used but depending on different chemical conditions. Other variants of both processes have also been tried. In all, over a hundred experiments have been made in the G.E. Laboratory, and each time diamonds have been found in the residue.

The artificial diamonds were proved to be pure diamonds by x-ray inspection, chemical inspection and hardness tests. In the latter, they proved capable of scratching anything, even other diamonds, and this means that this is the first man-made substance to scratch other diamonds.

The scientists concerned warn that it would be quite premature to conclude that it would soon prove possible to make diamonds of a size and quality suitable for gem use. But one of them has made a statement to the effect that if the present high cost of making diamonds by the new processes can be reduced, one can begin to think about the application of man-made diamonds in industrial tools for cutting and polishing.

MESCALIN: A CHEMICAL WHICH CAUSES HALLUCINATIONS

G. CURZON, B.Sc., Ph.D.

In 1560 Bernardino de Sahagun, a Franciscan monk, wrote a descriptive account of Mexico called *Historia General de la Cosas de Nueva España*. In this manuscript (one of the most important sources of knowledge of the Aztec civilisation), he described the effect on the native Indians of their habitual eating of a plant called peyotl. They were reported as experiencing "terrible and ludicrous visions". Peyotl gave them "strength and incited to battle; it alleviated fear, hunger and thirst". The plant was known as mescal in other parts of Mexico, and it was as "mescal buttons" that dried slices of it were sold and occasionally arrived in Europe. The Indians used the mescal plant in their religious rites to produce states of ecstasy in which the intoxicated person was thought to possess prophetic powers. Spanish missionaries tried persistently to discourage the eating of mescal buttons, but the habit spread through Mexico and among the Indians of the south-western United States. As late as 1918 a "peyotl church" was founded in New Mexico among christianised Indian tribes in which mescal-induced visions were combined with Christian symbolism, the mescal buttons being used in place of bread and wine in the communion service.

For four hundred years nothing was known about the nature of the mescal plant, until in 1886 Lewin collected specimens of a cactus to which the name *Anhalonium lewinii* was given (Fig. 2). More recently it has been renamed *Lopophora williamsii*.

Some years later Heffter, an organic chemist working at Leipzig, managed to obtain a very small sample of mescal buttons. From these he extracted a gummy material with alcohol, and by a series of further extractions and crystallisations from this he was able to obtain four alkaline organic substances. The simplest of these he called *mescalin*, and this was identified as the substance largely responsible for the hallucinations experienced by those eating the cactus. The dried cactus was found to contain up to 6% of its weight of mescalin. Other kinds of cacti were shown to contain this compound but in very much smaller amounts. Heffter himself was unable to determine the full chemical structure of mescalin. He did work out the various chemical groups it contained, but failed to discover the way they were arranged in the mescalin molecule. The mescalin he isolated was an alkaline substance that formed colourless crystals, and when treated with acids it was converted into crystalline salts.

PSYCHOLOGICAL EFFECTS

Now that the substance responsible for causing hallucinations had been isolated it was possible to study the mental effects more thoroughly. Very many psychiatrists and psychologists have described the effects of mescalin on themselves and on volunteers.

About half a gram of mescalin produces very marked psychological effects in normal human beings when it is injected or swallowed. About an hour after taking it the subject often feels nausea, but this state usually passes off and about two hours later the period of hallucination begins. The details of this vary from person to person, but some effects occur very frequently. The subject gets the impression that his body has become distorted, and individual parts of it may feel very large or small; he may even get the illusion that the whole of his body except the head does not belong to him at all. His sense of time may be grossly affected so that two or three minutes may seem to be as long as an hour. Optical hallucinations are fairly common, and the subject "sees" flashing lights and coloured patterns; stationary objects may seem to acquire an undulatory motion. Visions of actual objects and scenes are rather more infrequent. The subject is often very cheerful and in an exalted state of mind. He may have the impression of being able to think more clearly and easily than ordinarily, though his thought is actually based more on the sounds of words than on their meanings—thus puns come to pass for logical thought. But a large part of a mescalin hallucination is very difficult to describe verbally, the symptoms being entirely subjective and of a nature so different from normal experience that the subject cannot find words to describe them adequately. Ordinary objects may seem to have changed their size; a chair or a table, for instance, may seem to be larger than the room in which it stands, though at the same time the hallucinated person may realise that this is not objectively so.

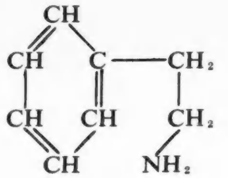
All these vivid impressions, so different from normal experience, often carry with them a feeling of being separated by an invisible barrier from the outer world. The hallucinations gradually fade over a period of a few hours, generally leaving no after-effects other than a slight hang-over.

When much larger doses of mescalin are given, a new symptom called catatonia occurs in which the subject may remain immobile for considerable lengths of time, in positions which may often appear uncomfortable and even grotesque to an observer. Animals may become catatonic when given mescalin, but as they are unable to describe their impressions the psychological effects must remain largely a matter for conjecture. The drug makes dogs and cats behave strangely; often they crouch in the corners of their cages and occasionally they will attempt to attack invisible assailants. Injection of mescalin into mice is followed by a period of twitching after which the animals proceed to go to sleep. Rabbits, on the other hand, are very resistant to mescalin.

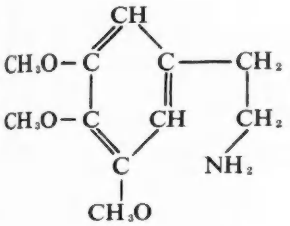
CAN ANIMALS MAKE MESCALIN?

In 1919 Spath, working in the same laboratory where Heffter had conducted his researches on mescal buttons twenty-five years before, managed to determine the

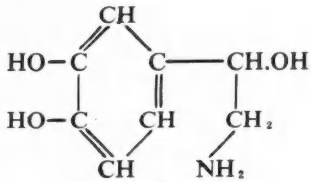
FIG. 1. THE STRUCTURE OF MESCALIN AND SOME RELATED COMPOUNDS.



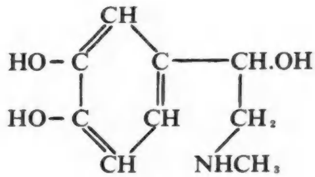
β-PHENYL-ETHYLAMINE



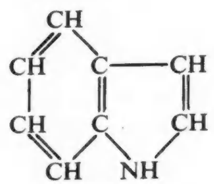
MESCALIN



NOR-ADRENALIN



ADRENALIN



INDOLE

structure of mescalin and to synthesise it. The chemical structure of mescalin turned out to be much simpler than that of most basic substances of plant origin. It is a derivative of β-phenylethylamine known as 3 : 4 : 5 trimethoxy β-phenylethylamine.

Now the chemical structures of adrenalin and nor-adrenalin are also closely related to that of β-phenylethylamine (although they are not actually derived from it in the body). Adrenalin and nor-adrenalin occur in the body in the adrenal gland and in the nervous system, and they are liberated into the blood during emotional states such as rage and fright. Nor-adrenalin also probably plays a part in the mechanism by means of which messages are conducted through the nervous system. The similarity between mescalin and these substances has prompted a number of workers to suggest that, in abnormal mental states such as schizophrenia, mescalin or a substance similar to mescalin may be produced in the body by the methylation of nor-adrenalin or of a nor-adrenalin precursor. In other words, it is suggested that a mental disease may be due to an abnormality in the chemical reactions going on in the body. This is an exciting idea, but in objection, it must be stated that no mescalin-like substance has yet been found to occur in animals. In particular, the methoxyl group, though common in substances of plant origin, is rare in animal biochemistry. Also the type of chemical reaction by which it could be made from nor-adrenalin is one that is very rare in animals; indeed only one example of it is known so far.

HOW MESCALIN BREAKS DOWN IN THE BODY

Substances like phenylethylamine are usually very easily destroyed in animals by the enzyme called amine oxidase, which is present in large amount in the liver and in lesser amounts in other organs. But mescalin is markedly resistant to the particular kind of amine oxidase possessed by humans; of a half-gram dose of mescalin taken into the body over 50% is excreted unchanged in the urine. Different animals are able to destroy mescalin to different extents. The rabbit destroys it easily—this links up with the fact already mentioned that mescalin has very little effect on this animal. Mice, like men, only destroy mescalin with difficulty. This fact has been made use of recently by Block at Marburg who has studied the chemical changes undergone by mescalin in the mouse, as a guide to what may happen when mescalin is given to human beings. Mescalin was prepared in which one of its carbon atoms was radioactive. The "labelled" drug was then given to mice. Their urine was then collected and its constituents separated on paper strip chromatograms. Mescalin and

FIG. 2. THE CACTUS FROM WHICH MESCALIN IS EXTRACTED.

its breakdown products travelled to different positions on the paper strip and were detected by their radioactivity. As well as large amounts of mescalin, and smaller amounts of the acid produced by the action of amine oxidase on it, a third substance of unknown nature was also found in small and variable amounts. This confirms the work of previous workers who reported an unknown mescalin breakdown product which, however, they were unable to identify chemically.

The fact that the psychological effects of mescalin usually occur some hours after taking the drug suggests that the action may not be due to mescalin itself, but to something else to which the body is able to convert part of it. The Marburg workers found that a small fraction of the mescalin given to mice became attached to the protein of the liver. The amount of this attached mescalin increased for a few hours after the mescalin was given and then gradually decreased. Now the liver is the main storehouse of the enzyme proteins. Some of these are able to convert poisonous substances which are produced by the body's chemistry into other less harmful materials. Thus if the mescalin in the liver is attached to enzyme protein it is possible that the power of the enzyme to destroy harmful substances which have psychological effects is impaired, and this could result in the accumulation of these substances.

OTHER HALLUCINOGENIC SUBSTANCES

There are few other substances known which have similar psychological effects to that of mescalin. (Such substances have been given the group name of hallucinogens.) The most interesting of these is lysergic acid diethylamide (commonly called LSD), which Stoll made in 1947. This is a simple derivative of lysergic acid, a substance found combined with various other chemical groupings in the alkaloids of ergot. Although these naturally occurring derivatives of lysergic acid do not have any effects at all like those of mescalin, LSD does so and in remarkably small doses. Injection of minute quantities ($0{\cdot}2 - 1{\cdot}0 \times 10^{-4}$ grams) has a marked effect on human subjects. The compounds known as harmine, ibogaine and adrenochrome have also been reported to have hallucinogenic power. The first two of these substances are bases of vegetable origin, while adrenochrome may be easily made in the test-tube by oxidation of adrenalin, though there is as yet no definite evidence that it may occur in the body. It has been pointed out recently that all three of these substances and also LSD have indoloid groups in their chemical structures. Mescalin, however, does not contain this group, but it is theoretically possible for the $CH_2—CH_2—NH_5$ chain of the mescalin molecule to curl round and the nitrogen atom to attach itself to the ring, thus forming a dihydroindole compound.

Interest in the hallucinogenic substances at present is mainly centred around the aid they may provide in the study of schizophrenia. Some workers think that the psychological state of a person intoxicated by mescalin is very similar to that of a schizophrenic. The sense of a barrier between the self and the outside world is common to both schizophrenics and normal people who have taken mescalin. There is as yet no general agreement that there is a similarity between mescalin intoxication and schizophrenia, but the ability we have to produce abnormal mental states by a simple chemical substance is having a stimulatory effect on the study of mental diseases from a biochemical point of view.

AUTOMATIC FACTORIES

S. LILLEY, M.Sc., Ph.D.

Automatic factories hit the headlines last October, and following close behind came the reissue of Chaplin's *Modern Times*. The latter reminds us that the dominant industrial trend of the last century or so (which automatic factories promise to reverse) has been the degradation of human beings from skilled workers to appendages of machines—appendages nearly as mechanical in their actions as the machines themselves. Chased by his fellow-workers, Charlie has only to restart the temporarily arrested conveyor and they all return to their places of work—switched on, as it were, along with the machine. Overcome by the monotony and the remorseless compulsion of the belt, he has gone mad and sees everywhere nuts to tighten—the foreman's nose, an office girl's buttons, and so on.

In fact, assembly workers do *not* go mad. Gaining a moderate living without the use of the higher parts of the cerebral cortex, they soon become incapable—through conditioning, rather than lack of innate ability—of undertaking creative activity or assuming responsibility. There is the aprocryphal story of the man who had spent years tightening one bolt on an everlasting stream of back-axles; he changed to a job in a canning factory, where he had to sort cherries as they came along a belt—black to the left, white to the right. Conditions were good, wages excellent. Yet at the end of the week he asked for his cards—"It's the responsibility that's getting me down," he explained: "Always decisions, decisions, decisions!"

It is my personal belief that one is only fully alive when one gets a creative joy from one's daily work. But the assembly worker or the automatic lathe operator gets little out of his job except the wage packet. Such dull repetitive work was perhaps an inevitable result of historical circumstances, but common humanity prompts the hope that it will not go on any longer than necessary.

Hard economic fact points the same way. In the past it paid the manufacturer to replace the skilled turner by the automatic lathe operator or to substitute human assembly-line appendages for that king of craftsmen, the fitter. It paid, because skill earned high wages and unskilled labour was cheap. But now the world has reached a situation in which its future prosperity depends on getting from every man the best he can give, on refusing to waste in unskilled routine any brain-and-hand combination that is capable of better things.

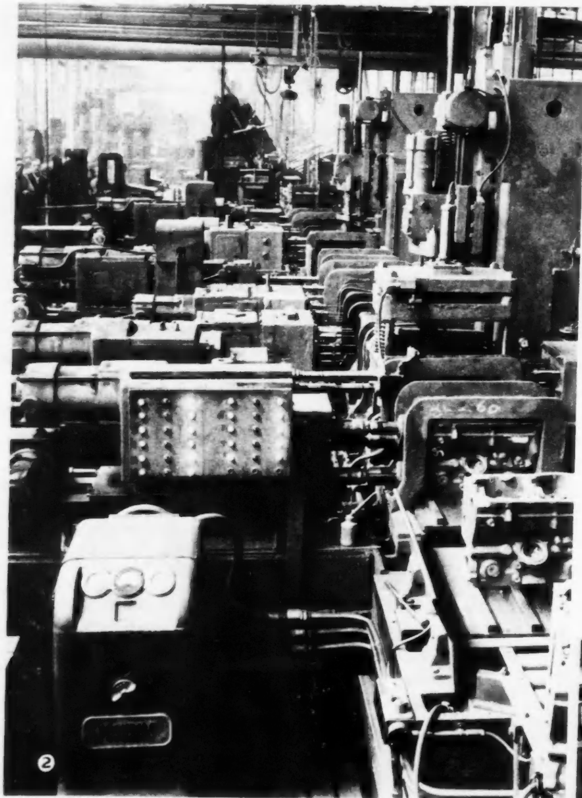
The production methods of the past hundred years have, in fact, actually concentrated on mechanising the more complex processes, because in that way wage costs could be lowered. The simpler processes—typified by those of the assembly-line worker—were left in human hands, because little further saving in the wage-bill could be achieved by mechanising them. As a result, the processes that must now be mechanised in order to eliminate repetitive labour are in essence the simpler ones (even though there may be complications in eliminating them all at once)—the loading of a rod into an automatic lathe, which is so very simple compared with what the lathe itself does, or the eternal placing of one bolt in one particular hole of the articles that flow past on the belt. Once a process has been reduced to the constant repetition of a few simple actions there can be no technical barrier to mechanising it. Seen in this light, the automatic factory, in which all unskilled labour will have disappeared, is technically possible, economically sound, and humanly desirable.

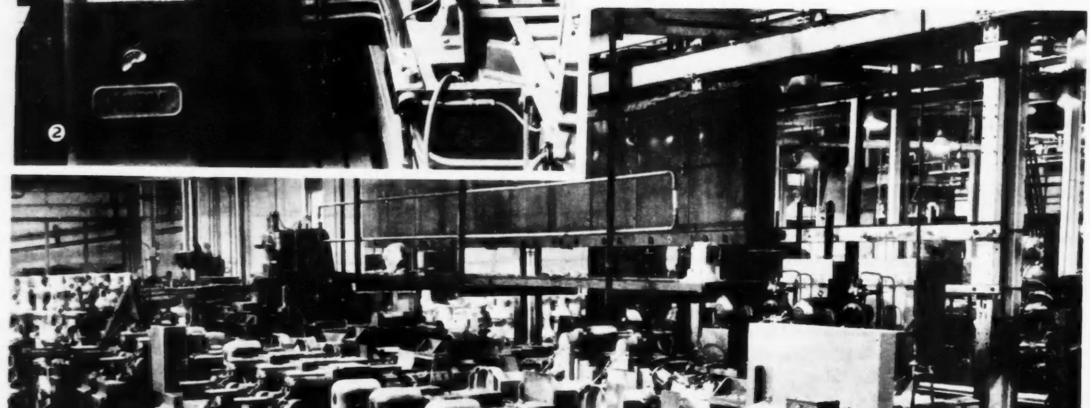
The idea is not so completely new as the recent stories in the daily Press might lead one to think. In the 1920's A. O. Smith & Co. of Milwaukee set up fully automatic machinery for the manufacture of motor-car frames. This is fed with strips of steel, which it passes automatically from station to station, while it cuts, bends and presses them, and punches rivet holes. Still automatically the various parts are brought together, riveted and finally brushed and cleaned and delivered ready for painting. Each frame takes 90 minutes to travel through the machine, but a frame is delivered every 10 seconds. The total staff numbers 120, mostly supervisory and maintenance, so that the transformation from steel strip to complete chassis costs about 20 man-minutes per frame. Even if we paid the whole staff at the rate of £2000 a year, the labour cost per chassis would be a little over six shillings!

TRANSFER MACHINES

Such ventures, however, remained rare in the inter-war years. But since the war large-scale application of highly automatic processes has come very much to the fore as the result of the development of what are known as *Transfer Machines* (Figs. 2–3). In the transformation of a casting into (say) a finished cylinder block like that of Fig. 1 by standard processes, the work passes along a line of machine tools, at each of which it is subjected to one or more operations of drilling, milling, boring, etc. The transfer of the work from one machine to another and the feeding of it into each machine in turn has hitherto been done manually (with or without mechanical aids from conveyors and the like). In 1939 a worker at the Stalingrad Tractor Works bethought himself of the saving that could be made by linking five lathes together by automatic conveyors to perform a sequence of ten operations without any intermediate handling. Other similar experiments were being tried elsewhere, and out of them has emerged the typical transfer machine of today, in which the work passes automatically through perhaps several dozen stations, at each of which several operations are carried out. Labour is used only for loading the blanks at one end and removing the finished pieces at the other.

Though in itself a modest example, the powers of a transfer machine may be conveniently illustrated by the thirteen-station machine at the factory of the Austin Motor Company in Birmingham, which produces the





AUTOMATIC UNITS AT LONGBRIDGE. FIG. 1. Cylinder blocks like these are produced by automatic transfer machines at Austin's Longbridge factory. FIG. 2. A 13-station transfer machine for cylinder blocks. FIG. 3. 17-station transfer machine for gearbox casings.

FIG. 1.
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cylinder blocks of Fig. 1, and for which some interesting details have been given by Mr. F. Griffiths, the firm's Chief Planning Project Engineer in a paper read to the Coventry Section of the Institution of Production Engineers, in November 1954. The operations it performs are as follows: drilling all holes in front and rear faces (except oil gallery holes); core drilling, semi-finishing, and finish boring of camshaft and crankshaft bores; facing, opening out and reaming oil pump bores; milling the cam clearance around the oil pump bosses; and facing the centre bearing crank thrust face. A general view of the machine is given in Fig. 2, in which the reader will be able to detect some of the tools that would normally be operating on a line of separate machines. Only two workers are involved, one loading and the other unloading (and even these might be eliminated by developing feeds from and deliveries to automatic conveyors). Work goes on simultaneously on blocks at all thirteen stations and when the cycle is completed each block "indexes" one station forward.

REDUCING PRODUCTION COSTS

Obviously such a machine saves enormously in labour costs. It costs 11*s.* per hour, against £2 17*s.* 2*d.* for an equivalent set of standard machines, while it turns out 3000 blocks a week compared with 2500 on the standard line. But what is more surprising, there is a saving in overheads too. This machine costs £25,903 to build and install, against £30,850 for the equivalent set of standard machines, and that implies corresponding economies in interest, depreciation, insurance, etc. It occupies less floor space, so that there is a saving of £79 per annum on rent. The annual power bill is reduced from £1069 to £765. When these and other relevant items are added together the total cost per hour of the transfer machine (including labour) works out at £4 4*s.* 3*d.* compared with £7 5*s.* 11*d.* by the older methods. And the cost per cylinder block produced is reduced from 2*s.* 4*d.* to 1*s.* 1½*d.*

This, as I have said, is a modest sample of a transfer machine, and Austins have already passed to much more advanced versions. But America appears to be ahead. For some years the American Ford plant has been using a machine which converts rough castings into finished cylinder blocks by 532 operations performed at twenty stations. *Automotive Industries* (1.12.54) described a 350-foot long machine performing 555 operations on 100 V-8 blocks per hour at 104 stations. The only direct labour is loading. The machine is divided into sections, any one of which can be shut down for tool-changing or maintenance, while the others continue work and parts are automatically stockpiled, waiting for the closed section to reopen.

Three illustrated articles in *The Machinist* (31.12.54; 14.1.55; 28.1.55) describe the latest steps in automatic working in the American car industry. The full text of these articles is well worth reading, and indeed it is difficult to do justice to them in a condensation. The reader must visualise lines of machines, each consisting of several transfer machines like those already described, with here and there a more specialised machine for some particular process, the whole connected by automatic transport, loading and unloading, so that the line acts as a single automatic unit. It will usually include inspection stations at frequent intervals, which automatically reject sub-standard parts. Sometimes there will be subsidiary automatic lines, making minor components and feeding them to the main line, where they will be automatically fixed to the main component. And, apart possibly from initial loading and final unloading, there is no direct labour involved—only supervision and maintenance.

As one example, a Pontiac cylinder-block line 1300 feet long contains nine transfer machines and six special machines with complete automatic handling between. After various milling, boring, drilling, reaming and chamfering operations, blocks are washed, and then the bearing caps (from an auxiliary line) are automatically put in place. Then comes rough and finish boring of cam- and crankshaft bearings and oil "sluggers", milling the ends of rear bearings and many other operations, ending up with a further washing, other finishing processes and final inspection.

In France, the Renault concern has been developing transfer machines since 1946, and now uses more than six hundred of them. Similar development has taken place in Russia. A gudgeon-pin line starts with cutting the blanks, and delivers five pins per minute, machined, plated, wrapped and boxed. And one Soviet plant (described in detail in *The Machinist*, 10.4.54) for making bearing races in up to fifteen sizes simultaneously has a special interest in that it was constructed from a set of old multi-spindle automatics (some as much as twenty years old) by adding automatic loading and unloading devices and connecting them through a conveyor system. Several units work in parallel on any one machining process, the conveyor system distributing the work among them. Man-hours are reduced 27% and machine utilisation increased 25%. This suggests that it may often be possible to turn existing plant into an automatic line, rather than face the cost of completely new machinery.

The automobile industry has naturally produced the most spectacular examples of automatic production, but the same sort of thing is happening in other trades. A recently installed American iron-casting machine replaces the labour of forty men by the skill of six. On a capital investment of 600,000 dollars it saves 300,000 dollars a year in wages. The output depends on the size of the castings, but it will (for example) produce 3600 2½-lb. castings per hour. A change from one job to another takes a mere 30 seconds. Another machine, attended by two people, makes electrical resistors, calibrates and classifies and packs them at the rate of 3000 per hour, formerly the output of eighty-two workers Automatic lines in coil-spring manufacture and in shell manufacture have reduced labour requirements to about 15% and 7½%, respectively, of what they used to be. A machine for making thermometers replaces twenty-two workers by one, and uses 10 square feet of floor space against a former 6000 square feet.

AUTOMATIC ASSEMBLY

Automatic assembly, too, is beginning to attract attention. A machine is reported which assembles a carburettor of eight pieces, formerly the job of four men, under the attention of one, and at the rate of 625 per hour. An automatic toggle-switch assembly reduced direct labour costs from 18 cents to less than 1 cent per article. There is an enormous amount of unskilled labour that could be eliminated in this way, and if the trend has not yet gone far, it is obviously something that is coming soon in a big way—Renault, for example, have declared that they are introducing it.

Though some of these overseas examples are much more elaborate than anything in Britain, it is good to know that the progressive attitude of Austins is ensuring that we do not fall hopelessly behind on this line of development as we have so often done in the past. What they have achieved has been done in the face of great difficulties. The British machine-tool industry does not seem to take much interest in this type of development, and Austins have succeeded in interesting only one machine-tool firm, James Archdale & Co., in their venture. The actual construction of the machines has been shared between Austins and Archdale, with Austins taking the major share and establishing for that purpose what amounts to a new factory within a factory. By contrast, over thirty U.S. firms are engaged in building transfer machines or similar devices.

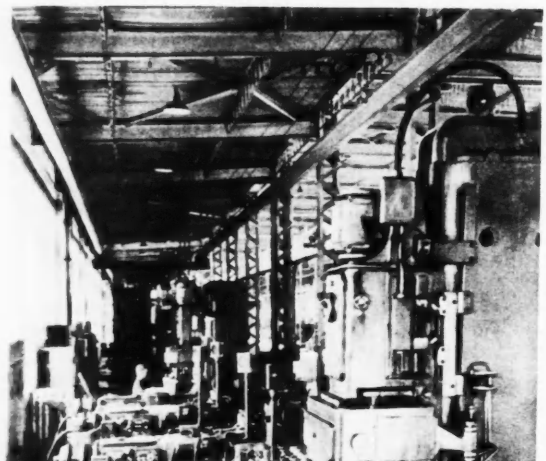


FIG. 4. General view of the production line at the Stankokonstruktsia automatic piston factory.

Mr. Griffiths, at the end of the paper already referred to above, makes some interesting speculations about future trends. The objection that transfer machines can be useful only to large organisations needing large quantities of standard parts he answers by visualising more adaptable versions that can be easily changed from one job to another—or even machines that will take on several jobs simultaneously, each component as it passes operating a series of trips and dogs that would select the appropriate tools to work on it. And he ends with the words: "I would like to suggest that the Transfer Machine of the future will take in the raw material at one end, cast it or forge it, machine it and deliver the finished component, either ready painted and packed or to the assembly point where it is required."

This last prophecy has been anticipated by fact in the Stankokonstruktsia plant for making car pistons which started work on the outskirts of Moscow in 1950 or 1951 (Figs. 4–5). This factory, which supplies pistons for the entire Russian light car industry, is worked by a staff of nine men on each shift: one general controller at the electronic nerve-centre; a labourer who loads aluminium ingots on to a conveyor at the beginning; two machine-minders on the line; and five skilled maintenance men. Apart from the initial loading, all processes and all transfers throughout the 50-yard line are entirely automatic. Labour is used only to care for the machines. The ingots are tipped by the conveyor into an electric furnace. The melted aluminium in automatically weighed batches is poured into moulds, which open after the appropriate time to eject the castings. These are then trimmed (the trimmings returning automatically to the furnace) and pass still hot into an annealing furnace. Next comes an automatic hardness checker, from which any rejected castings are returned automatically to the furnace for remelting. Castings that pass the test are delivered as required to the engineering section (in effect a transfer machine like those already described), where at a series of stations they are turned, bored, ground, grooved and polished. One worker takes charge of the engineering line. The necessary inspection is done automatically. Wear of tools is automatically compensated until replacement becomes necessary. The pistons then move to the chemical section, supervised by a third worker, where they are degreased, washed, tinplated and then polished a second time. Next comes final inspection—to tolerances of about a ten-thousandth of an inch. Even at this high standard, rejects are claimed to be only 4%. All this time four different sizes of pistons have been passing along the line, the machines automatically adjusting themselves to each size as required. In final inspection the four varieties are sorted out and stamped accordingly, ready for packing (Fig. 5). And then in the packing section the pistons are greased, wrapped in parchment paper, packed in boxes of six and stacked ready for collection.

More than 1500 electrical instruments control the entire process. If a breakdown occurs, the machine

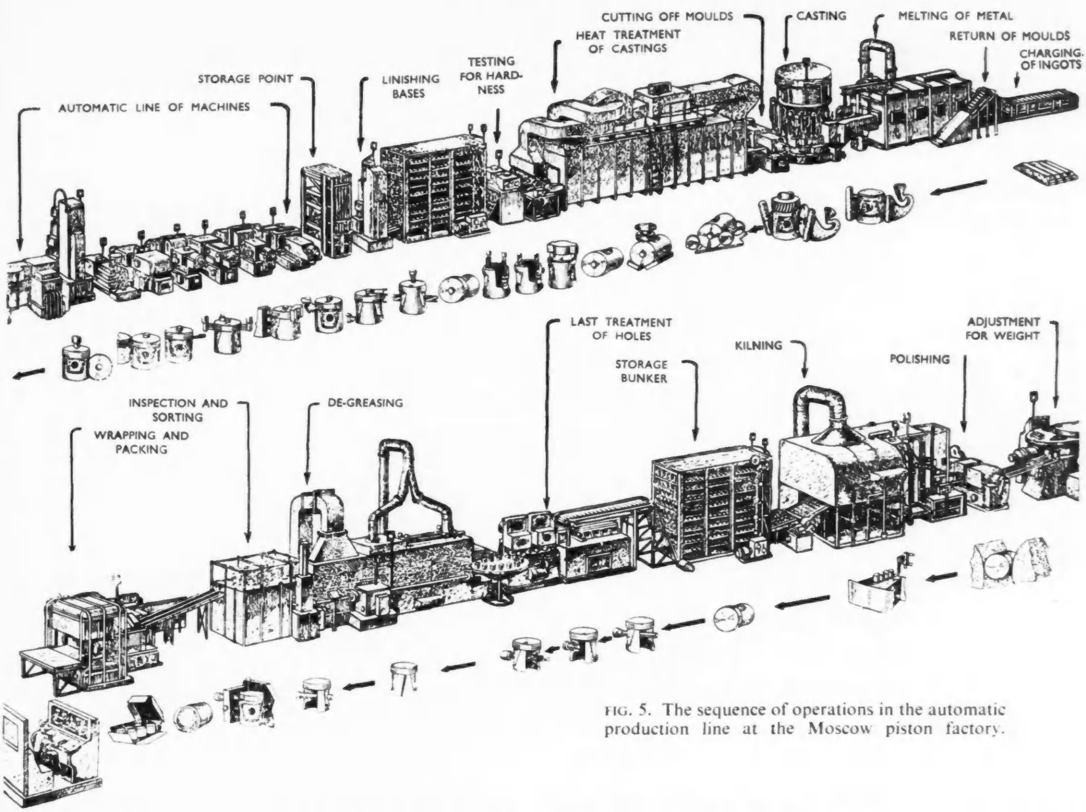


FIG. 5. The sequence of operations in the automatic production line at the Moscow piston factory.

involved stops automatically, and lights a signal lamp at the control desk. The controller phones one of the men on the line or one of the maintenance workers to have the fault attended to.

This factory is claimed to cut total staff to one-quarter of that previously required, manual workers to one-sixteenth, and production costs to one-half. The output is 3500 piston heads per 24-hour day, so that each piston takes less than 4 man-minutes of work. The rise in the average level of skill employed is very notable. The only unskilled worker is the man who loads ingots on to the initial conveyor—and surely a little thought would enable him to be eliminated from the Mark II model of this factory. The status of the two machine-minders on the line is not clear, but they must at least be semi-skilled. And the controller and the five maintenance men belong to the highest industrial ranks.

The American Pontiac concern has now set up a rather similar line for making pistons for their 1955 models. It does not include the casting and heat treatment, but has the higher production rate of 200 per hour.

The Moscow plant gives us a glimpse of the automatic factory of the future which will make machines do all but the most skilled work and at the same time cut production costs to some small fraction that we can hardly begin to guess. Yet it is no more than a glimpse. This factory produces only one part. Something like 4000 parts go to the make-up of a modern car. We are still a long way from an automatic factory which will make all these parts, bring them together in the right places, assemble them and deliver the car ready to drive away.

Even when assembly is done by manual labour working alongside conveyors, the problem of bringing components to the correct places as and when required is a serious one. Dozens of separate lines making the engine, the chassis, the body and the hundreds of minor fittings must be co-ordinated so that final assembly can run smoothly. The problem was not so serious in the days when Ford could say that his customers could have the T-model in any colour they liked provided it was black. But nowadays a single line will be producing many versions of the same basic model—with variations of body type and colour, various upholsteries, left- and right-hand drive, perhaps engines of different capacities and choice of synchromesh, preselector and automatic gear-box, as well as various optional fittings from over-drives to radios and heaters. Almost any combination of these may occur, successive cars on the line involving quite different assemblages, and the material handling side of factory organisation must arrange that each component (coming from some subsidiary line or store)

meets the correct chassis at the appropriate place on the line and dead on time.

To cope with this sort of thing, Austins have embarked on an ambitious scheme for controlling the movements of the various parts by a Hollerith punch-card system. Though only a small part of the scheme is yet working, the ultimate aim is that every individual car will start life as a pattern of holes punched in a card, which will specify exactly what components are required. A stack of cards representing the production schedule will then be fed to a machine, which will read the patterns and by electrical connexions will automatically release all the components in such a way that each arrives at its assembly point exactly when wanted.

In imagination one could extend this method to the point at which every little screw and every major casting starts its life at just that moment which will ensure that it can smoothly pursue its complicated journey through the factory, meeting this and that other component, becoming built into larger and larger assemblages, until at last all the parts needed to make a car have been assembled in their correct places without hitch or delay, and with a minimum of capital-wasting stockpiling. Such a vast control scheme is clearly beyond the capacity of even the Hollerith system. But it is probably well within the reach of an "electronic brain".

Let us assume that it is, and let us further assume that the individual cylinder blocks, piston heads, gears and gear-box casings, and all the rest, are produced by automatic machinery like that described above; and that the loading and unloading operators have been eliminated by arranging for the automatic caster to deliver direct to the transfer machine (as in the Moscow piston factory); and finally that assembly has also been made automatic (as latest trends foreshadow). Then we have a vision of the automatic factory as it may appear in the not-too-distant future. It will consist of a number of departments, each of which would be like the Moscow factory, or one of the more elaborate American lines, together with all the relevant assembly lines, working equally automatically. And controlling the whole lot would be an "electronic brain", fed with the production schedule, issuing automatic instructions that would ensure that all departments work in step, that every one of the 4000 items that constitute a car is made when wanted and delivered as required to the point where it must be joined to other parts. The "brain" would also be kept constantly informed about how the machines were behaving. It would note breakdowns (or better still, anticipate them by keeping an eye on the temperatures of bearings and the dimensions of parts produced) and it would notify the maintenance men to take appropriate action.

These maintenance men—at present near the top of the industrial tree—would now be the lowest rank of worker. In addition there would be the highly specialised maintenance staff of the "electronic brain", as well as the mathematical technicians charged with translating the production schedule into terms that the "brain" can "understand". There would be a management grade to take major policy decisions. And behind all this there would be the machine builders, the machine designers and the research staff constantly looking for yet more efficient ways of doing things.

Socially what does this all imply? Obviously as great changes in our way of living as those induced by the 18th- and 19th-century Industrial Revolution, and probably coming upon us much more rapidly. Some American Trade Unions are already worried about possible large-scale unemployment, as automatic factories cut labour requirements, and all the misery that implies. Clearly this might be a serious transitional problem. But it should not be beyond human ingenuity to reorganise social institutions, so that at first the vastly increased production is used to raise the standard of living of the hundreds of millions who still live at subsistence level; and when this has been done to introduce an eight-hour working week, or perhaps provide free full-time education till the age of thirty and pensioned retirement at forty! If the machines can make what we want for very little labour, there is no *natural* difficulty in distributing the products so that all may share them.

NEW DIRECTOR-GENERAL OF CERN

The successor to Prof. F. Bloch as Director-General of CERN will be Dr. C. J. Bakker, Professor of Physics at University of Amsterdam. Prof. Bloch's resignation takes effect in August.

Dr. Bakker, who was born in 1904, studied physics under Zeeman in Amsterdam. In 1931 he took his doctorate, and then came to London where he spent a year at the Imperial College of Science continuing his work in the field of spectroscopy.

In the following year he became a member of the scientific staff of Philips, Eindhoven, where he did research on certain physical problems in relation to radio. His interests gradually turned to nuclear physics, and after the war he became Director of the Institute of Nuclear Physics, the focal point of Dutch nuclear research sponsored by F.O.M. (Fundamenteel Onderzoek der Materie), by the city of Amsterdam and by Philips.

He is a member of the Dutch Reactor Committee, and as such a member of the Joint Dutch-Norwegian Committee, which operates the joint reactor at Kjeller in Norway.

In 1951 he was invited by Prof. Auger, the Director of the Unesco Department of Natural Sciences, to act as one of the eight experts to draw up plans for the future CERN.

RADIOACTIVITY AND PLASTICS

Research and development work done at Harwell on the improvement of the physical properties of plastics such as polythene, nylon, silicone rubbers, polyvinyl chloride and neoprene has now reached the stage where commercial firms are actively concerned.

Dr. A. Charlesby who initiated this work has now found that the exposure of plastics to irradiation has different effects on different kinds of plastics. In the case of plastics such as polythene and polyvinyl chloride which have one side-chain in their molecules, the effect of irradiation is to cause cross-linking between the molecules, giving them increased strength and heat-resistance. In the case of plastics such as Perspex, PTFE (polytetrafluoroethylene) and poly-iso-butylene, which have two side-chains to each molecule, the irradiation causes a degradation, or breaking up of the structure of the plastic.

The potential industrial importance of the use of this irradiation technique is thought to be considerable, as it can lead to a substantial improvement of such qualities as strength and the heat-resistance in the case of the first category of plastics mentioned above.

Irradiation can improve the strength of polystyrene to an extent where a small amount of this substance can carry up to a hundred times its own weight. The heat resistance of polythene can be improved by irradiation to an extent that polythene cable insulation which would normally melt at 70°C (and become liquid at 115°C) will withstand working temperatures of from 200°C to 300°C. Such irradiated polythene can also be heat-sterilised—a factor which is important where it is used for medical purposes.

Another effect of the exposure of plastics of this type to radiation is concerned with shaping and moulding. If an irradiated polythene tube is blown into a mould while it is heated to a temperature of about 115°C (at this temperature the irradiated polythene becomes malleable) and then cooled, it will retain that shape indefinitely until it is reheated to the same temperature when, of its own accord, it reverts to its original tube shape.

Irradiation also affects the reaction of materials such as polythene to solvents. Chemical compounds which had previously caused the plastic to dissociate and break down cease to act as solvents although they may cause it to swell. One effect that may be disadvantageous is the increase in the brittleness of the plastic caused by irradiation. This effect, like the other changes in the physical qualities of plastics (including those such as Perspex where the irradiation causes them to break down) can, however, be controlled, since the physical effects caused by the irradiation are related to the dosage of radioactivity to which the plastics are exposed.

One further point recently discovered by Dr. Charlesby, which may prove of considerable interest in the field of medical science, is the fact that when substances which cut down the harmful effects of radiation on biological tissue are added to polymers in solution in water the effects of the radioactivity of the polymer in the solution is similarly reduced.

GIANT CLAMS

PROF. C. M. YONGE, F.R.S.

Department of Zoology, University of Glasgow

Among the most striking of the many unusual and often spectacular inhabitants of coral reefs in the Indian and Pacific Oceans are the Giant Clams. These are the largest of bivalve molluscs, not merely at the present time but throughout all geological time. Commonly they reach a length of over four feet and a breadth and a height of over two feet. There are authentic records of speciments over six feet long and stories of others far larger. The shell itself is two inches thick in places, and the animal within is massive. The largest clams weigh many hundredweight. Living unattached on the surface of a reef, exposed to the full fury of seas that pour over it with the rising tide, they rest immovable owing to their great weight (Fig. 6).

The recorded history of these animals goes back many centuries, and it is known that their enormous shells were early brought to Europe by the land route from the Persian Gulf. In the church of St. Sulpice in Paris the holy-water basins consist of a pair of these shells said to have been presented to Francis I in the 16th century. Captain Cook encountered these clams reporting that one of these "Gigantic Cockles" was more than a sufficient meal for a hungry sailor! In the Torres Strait Islands, the later explorers, Matthew Flinders and the Frenchman, Dumont d'Urville, found these great shells, arranged under the drooping leaves of the Pandanus palms, being used to collect rain water.

Later still these clams attained notoriety as a menace to pearl divers. It is true that an incautious hand or foot placed between the open shell valves will be held firmly by contraction of the thick connecting muscle. But a strong knife can be forced between the valves to sever the muscle, and the clam is then helpless.

There is much of great interest about the animals, quite apart from their impressive size. The Giant Clam, *Tridacna deresa*, is the largest of a highly characteristic group of bivalves. All the species in the genus *Tridacna* are large when compared with our own cockles, mussels and oysters, the smallest being some 5 inches long with others a foot or more in length. There is also the closely related Horse-hoof Clam (in side view this looks very like a hoof) of the genus *Hippopus*. The two genera make up the family Tridacnidae.

These clams probably all move about somewhat in early life but soon become immobile, attaching themselves, like mussels, by means of byssus threads. These horny fibres are formed by a gland in the base of the animal's "foot". The substance of the thread, like a fluid plastic, flows along a groove in the foot which, by appropriate movements, plants each thread on the rock where it immediately sets. Mussels and other bivalves live all their lives so attached and can withstand powerful seas. In some of the smaller clams also the byssus persists, but in others, including the Giant Clam and the Horse-hoof Clam, this attachment is lost when the animal reaches a certain size. The gape between the shell valves through which the threads project then closes, and from that time the clams maintain themselves in position solely by their weight.

Of the clams which remain attached, many bore into coral rock, indeed in some areas boulders are literally studded with their borings. These animals are up to 5 inches long and some 2 inches deep and wide, but when the rock is uncovered by the sea all that can be seen are the free margins of the shell valves which are held tightly together and lie just flush with the surface of the rock. When this is broken into, the clams inside it are revealed, each living within a cavity of its own making to which it is fastened by a stout bundle of byssus threads.

Many bivalves bore into rock; the piddock is a common example in Britain, while in the Mediterranean there exists the date mussel which inhabits only calcareous rocks, boring into them by means of an acid secretion. All these animals penetrate with the anterior end foremost; from the hind end project the siphons through which water for feeding and respiration enters and leaves the internal cavity (see Fig. 1). It is clearly to the animal's advantage to be able to bore; it is exceptionally well protected in its burrow, and it can feed there and respire just as well as if it had remained on the surface like a mussel, or had burrowed in sand like a cockle.

Clams, however, bore in a manner all their own. Fastened initially to the surface of the rock, they bore straight down into this, sinking, as it were, into the rock below (Figs. 4–5). The boring process is purely mechanical, and is carried out by means of the stout ribbed shell which is rocked by powerful muscles.

In life, these clams are unexpectedly beautiful. When Boring Clams are viewed under water no shell is visible, this and the opening of the boring are completely obscured by a broad and vividly coloured band of tissue with scalloped margins. In the smaller boring clams these tissues are usually blue but in larger ones, the so-called frilled clams, they are the most vivid objects on a coral reef. They may be blue, purple, orange, brown, yellow, green; almost every shade and every combination of these colours occurs, and no two individuals have quite the same colour pattern. In the giant clams, as becomes their size and dignity, the colour is a sober olive green with emerald spots (Fig. 3). The Horse-hoof Clam differs from the Tridacnas because these tissues, always of dull green, never extend over the margin of the shell valves, but these gape widely so exposing the tissues that stretch between them.

We have next to consider the nature of these extended and pigmented tissues. Amongst our own population of bivalves those most closely related to these clams are cockles. If a living cockle be observed in water, all that is usually exposed are the short siphons that project at

the posterior end although, when the animal moves in the sand, a muscular sickle-shaped foot is protruded on the under side. There is nothing here corresponding to what one sees in the clams. The clams have altered in form in a most remarkable way and with truly extraordinary consequences, and they differ markedly from all other families of bivalves.

In Fig. 1A is shown a cockle with its siphons and foot protruding from between the shell valves, and alongside it for comparison is a drawing of a clam; in the latter case, the byssus threads (for the drawing shows an *attached* clam) appear in place of the foot which forms them but seldom itself protrudes. With the foot and the byssus of the two animals as a fixed point, the shell has swung round in the longitudinal vertical plane in relation to the body within. This is best shown by the position of the hinge, which has moved through an angle of 180° from the upper side opposite to the foot to the under side alongside the foot (and byssus). Observe too how in the clam this rotation of the shell has had the additional effect of extending the siphons from the posterior end, where they are confined in the cockle, right along the upper side of the animal. The two openings are now widely separated, whereas they are side by side in the cockle. Water enters through the slit-like opening at the posterior end, and is ejected by way of the rounded opening which points directly upward in the middle. Among the spectacular sights on a reef when the tide is low are the sudden spouts of water that are thrown high into the air when the larger clams close or partially close the shell valves forcing out water through this opening. But as well as extending for such length along the entire upper surface, these siphonal tissues have also spread out laterally so that when fully expanded the shell is invisible from above.

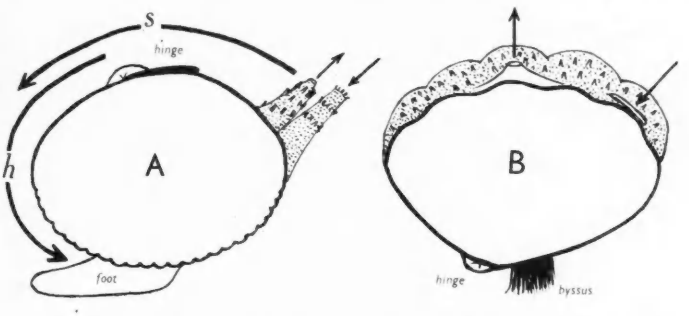
This then represents the surprising difference between these clams and all other bivalves. The shell and the "mantle" which forms it have rotated in relation to the foot and the other internal organs, and the siphons have become immensely extended in length and breadth, and now face directly upwards instead of backwards. So that in one sense the boring clams do enter rock like other boring bivalves in that the siphons alone project out of the boring.

AN EXAMPLE OF SYMBIOSIS

What advantage, one may now reasonably ask, is conferred on the clams by possession of these brightly coloured siphonal tissues which remain fully expanded so long as they are even barely covered with water, the temperature of which, when fully exposed to tropical sunshine, may be well over 30°C? The answer is revealed when one draws a knife over the surface of these exposed tissues and then examines under the microscope the brownish scum so obtained. This is seen to consist almost entirely of a mass of minute single-celled plants, each brown in colour, spherical and about one-hundredth of a millimetre in diameter. These are known as *zooxanthellae*.

Sections through the siphonal tissues show that these contain millions of these plants which are largely massed in the blood channels that ramify everywhere. They are individually contained within blood cells of the mollusc, but clearly they are able to flourish within these because they are frequently seen dividing. Now the function of these tissues becomes clear; they make it possible for the clams to farm a vast flora of microscopic plants. The greater the surface area the more plants can be housed and exposed to sunlight; the harmful effect of the sun's rays on the animal cells is prevented by their intense pigmentation.

But further study of sections reveals also that the upper surface of the siphonal tissues is dotted with many minute lens-like structures (Fig. 2). At first examination these appear to be eyes. But careful study reveals no trace of retinal surface on which light could be focused nor indeed of any nerve to carry impulses. While it is probable that these structures do represent the remains of eyes (which are present in the siphons of the related cockles), their function now is plainly to focus light deep into the tissues for benefit of the contained plants.



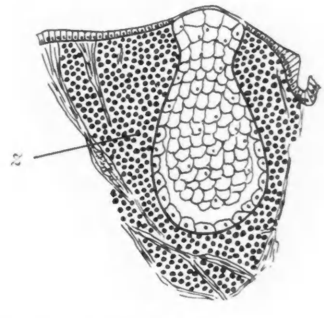


FIG. 1 (*left*). A–B. Diagram showing changes of form from a Cockle (A) to a Clam (B). The siphonal tissues in both are shown stippled with arrows showing the ingoing and outgoing currents. The curved arrows in A indicate *h* the movement of the hinge and *s* the extension of the siphonal tissues which have occurred during evolution of the Tridacnidae.

FIG. 2 (*right*). Section (greatly enlarged) showing a lens structure from the upper surface of the siphonal tissues in a Clam; great numbers of the unicellular plant cells or zooxanthellae (*z*) are also shown.

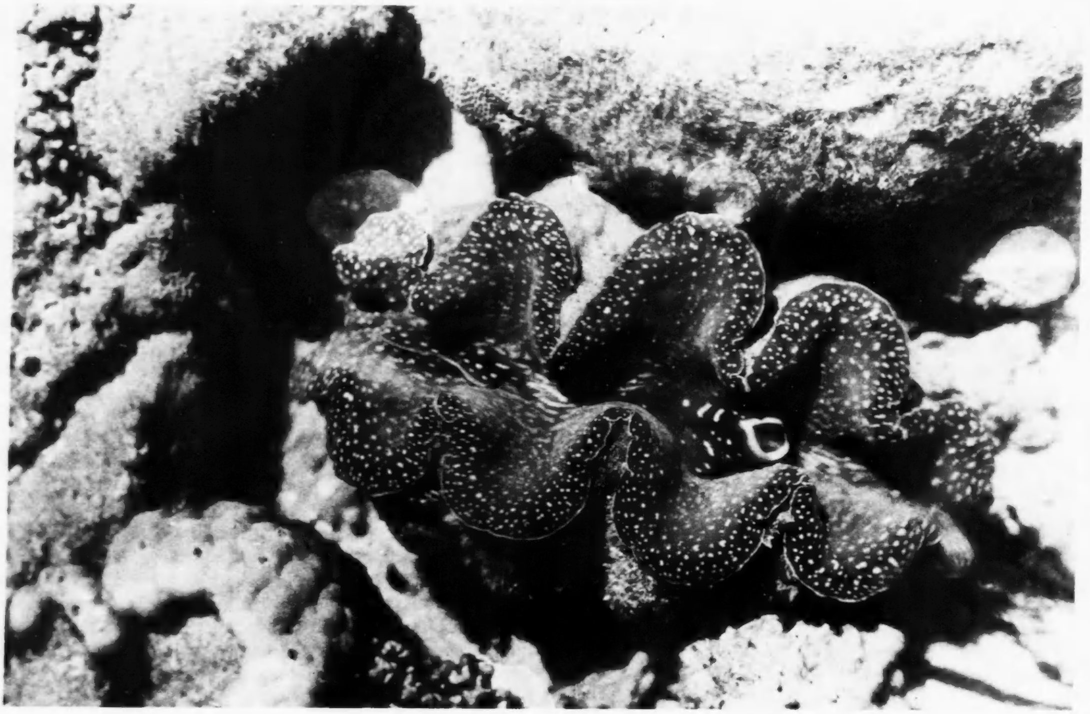


FIG. 3. Giant Clam viewed from above when fully expanded under water. Note the great extension of the siphonal tissues over the margins of the shell valves, also the large outgoing siphon.
FIG. 4. Coral boulder exposed at low tide containing many specimens of the Boring Clam (*Tridacna crocea*) each some 5 inches long and all with shell valves closed.
FIG. 5. Boring Clam viewed under water; the animal's blue siphonal tissues are fully extended and completely obscure the shell and boring.

We are dealing here with an example—and an unusually complex and beautiful example—of interdependence or symbiosis between an animal and a plant. The zooxanthellae live protected within the tissues of the clams; they are fully exposed to light—for the clam only closes the shell when actually exposed to the air—and have abundant food from the waste products of the animal. These include carbon dioxide and water, which would be equally available in the sea, but also nitrogenous waste and phosphates. These are far from abundant in sea water where, like the similar plant nutrients on land, they control the plant crop which in this case is microscopic plant plankton. But in the animal these nutrients are constantly being formed owing to breakdown of proteins. They are then seized on by the contained plants to build up new proteins. It is interesting to compare the excrement of a clam with that of another bivalve of similar size, both being kept in jars of sea water. In the latter the quantities of plant nutrients in the water rapidly increase, but with the clams nothing is added to the water, and indeed any nutrients previously present in the water are removed. The plants, in other words, act as organs of excretion to the animals, automatically removing waste as quickly as it is formed.

EXTRA SOURCE OF FOOD

But what of the animal? Examination deeper in the body, in the region around the gut, reveals vast numbers of plants, each living within a blood cell but now in varying stages of digestion. Blood cells, it may be noted, do normally take part in digestion in bivalve molluscs although usually obtaining food particles from the gut. There is no doubt that the clams feed to a very large extent on the microscopic zooxanthellae which they farm in their brightly coloured siphonal tissues. But, unlike many other animals that also harbour plant cells, the clams have not lost the power of feeding in the usual manner. This they do, like all other bivalves, by drawing in water through the one siphon and then filtering off the finely divided food particles, largely microscopic plant plankton. This food is then passed to the mouth while the water leaves by the other siphon.

Undoubtedly, however, the clams are far less dependent than are other bivalves on this free living plant plankton from the sea. They have augmented supplies by farming their own crops, exposing them to light and providing food from their own excrement. One begins now to see how the change in form which has resulted in the evolution of the Tridacnidae may have come about. Some local invasion of the siphonal tissues by plant cells took place, following which any tendency for further extension and exposure to light of the siphons would give greater and greater advantage to the animal in the form of more "cultivated" food. There would be, as we put it, "survival value" in any further rotation of the mantle and shell which exposed and extended the siphons and so enabled more plants to be farmed.

FIG. 6. Side view of a Giant Clam (*Tridacna deresa*) largely exposed by the falling tide on a reef of the Great Barrier of Australia. Specimen about 3½ feet long.

Returning now to the great size of the Giant Clam itself, here it may, I think, be reasonably argued that there is probably a size which cannot be exceeded by any animal which feeds, as do bivalve molluscs and many other aquatic animals, by sieving fine particles from suspension in water. But this size may well be exceeded if the animal acquires a subsidiary source of nutrition, one moreover which represents almost a closed cycle, the animal nourishing the plant by its excrement, the plant returning this, as protein, to the animal. The one external factor is the energy of sunlight to which the clams so widely present themselves.

Just one final point: dependent as they are on sunlight, and apparently very powerful sunlight at that, the Tridacnidae live only in shallow water and in the very hottest seas. They are among the few marine animals which do not spawn until the temperature reaches about 30°C—and such a temperature is only reached in the surface waters of the mid-tropics in the height of summer.

THE BIRTH OF THE ATOMIC AGE

LAURA FERMI

Laura Fermi's biography of her husband, Enrico Fermi, who died on November 28, 1954 (both of them are seen in the photograph alongside), has just been published in this country by Allen & Unwin. These extracts from her book, which is entitled "Atoms in the Family", are interesting for the pictures she gives of life at Chicago when the first atomic pile was operated, and at Los Alamos.

The period of great secrecy in our life started when we moved to Chicago. Enrico walked to work every morning. Not to the physics building, nor simply to the "lab", but to the "Met. Lab", the Metallurgical Laboratory. Everything was top secret there. I was told one single secret: there were no metallurgists at the Metallurgical Laboratory. Even this piece of information was not to be divulged.

The best place Prof. Arthur H. Compton [director of the Metallurgical Laboratory] had been able to find for work on the pile was a squash court under the West Stands of Stagg Field, the University of Chicago stadium. President Hutchins had banned football from the Chicago campus, and Stagg Fields was used for odd purposes. To the west, on Ellis Avenue, the stadium is closed by a tall, grey stone structure in the guise of a medieval castle. Through a heavy portal is the entrance to the space beneath the West Stands. The squash court was part of this space. It was 30 feet wide, twice as long, and over 26 feet high.

The physicists would have liked more space, but places better suited for the pile, which Prof. Compton had hoped he could have, had been requisitioned by the expanding armed forces stationed in Chicago. The physicists were to be contented with the squash court, and there Herbert Anderson had started assembling piles. They were still "small piles", because material flowed to the West Stands at a very slow, if steady, pace.

Success was assured by the spring. A small pile assembled in the squash court showed that all conditions—purity of materials, distribution of uranium in the graphite lattice—were such that a pile of critical size would chain-react.

* * *

While waiting for more materials, Herbert Anderson went to the Goodyear Tyre and Rubber Company to place an order for a square balloon. The Goodyear people had never heard of square balloons, they did not think they could fly. At first they threw suspicious glances at Herbert. The young man, however, seemed to be in full possession of his wits. He talked earnestly, had figured out precise specifications, and knew exactly what he wanted. The Goodyear people promised to make a square balloon of rubberised cloth. They delivered it a couple of months later to the squash court. It came neatly folded but, once unfolded, it was a huge thing that reached from floor to ceiling.

The squash court ceiling could not be pushed up as the physicists would have liked. They had calculated that their final pile ought to chain-react somewhat before it reached the ceiling. But not much margin was left, and calculations are never to be trusted entirely. Some impurities might go unnoticed, some unforeseen factor might upset theory. The critical size of the pile might not be reached at the ceiling. Since the physicists were compelled to stay within that very concrete limit, they thought of improving the performance of the pile by means other than size.

The experiment at Columbia with a canned pile had indicated that such an aim might be attained by removing the air from the pores of the graphite. To can as large a pile as they were to build now would be impracticable, but they could assemble it inside a square balloon and pump the air from it if necessary.

When the balloon was secured on five sides, with the flap that formed the sixth left down, the group began to assemble the pile inside it.

From the numerous experiments they had performed so far, they had an idea of what the pile should be, but they had not worked out the details, there were no drawings nor blueprints and no time to spare to make them. They planned their pile even as they built it. They were to give it the shape of a sphere of about 26 feet in diameter, supported by a square frame, hence the square balloon.

The pile supports consisted of blocks of wood. As a block was put in place inside the balloon, the size and shape of the next were figured. Between the squash court and the nearby carpenter's shop there was a steady flow of boys, who fetched finished blocks and brought specifications for more on bits of paper.

When the physicists started handling graphite bricks, everything became black. The walls of the squash court were black to start with. Now a huge black wall of graphite was going up fast. Graphite powder covered

the floor and made it black and as slippery as a dance floor. Black figures skidded on it, figures in overalls and goggles under a layer of graphite dust. There was one woman among them, Leona Woods; she could not be distinguished from the men, and she got her share of cussing from the bosses.

The carpenters and the machinists who executed orders with no knowledge of their purpose and the high-school boys, who helped lay bricks for the pile, must have wondered at the black scene. Had they been aware that the ultimate result would be an atomic bomb, they might have renamed the court Pluto's Workshop . . .

To solve difficulties as one meets them is much faster than to try to foresee them all in detail. As the pile grew, measurements were taken and further construction adapted to results.

The pile never reached the ceiling. It was planned as a sphere 26 feet in diameter, but the last layers were never put into place. The sphere remained flattened at the top. To make a vacuum proved unnecessary, and the balloon was never sealed. The critical size of the pile was attained sooner than was anticipated.

Only six weeks had passed from the laying of the first graphite brick, and it was the morning of December 2.

* * *

There is no record of what were the feelings of the three young men who crouched on top of the pile, under the ceiling of the square balloon. They were called the "suicide squad". It was a joke, but perhaps they were asking themselves whether the joke held some truth. They were like firemen alerted to the possibility of a fire, ready to extinguish it. If something unexpected were to happen, if the pile should get out of control, they would "extinguish" it by flooding it with a cadmium solution.

Among the persons who gathered in the squash court on that morning, one was not connected with the Met. Lab.—Mr. Crawford H. Greenewalt of E. I. du Pont de Nemours. In a pile, Mr. Greenewalt was told, a new element, plutonium, is created during uranium fission. Plutonium would probably be suited for making atomic bombs. So Greenewalt and his group had been taken to Berkeley to see the work done on plutonium, and then flown to Chicago for more negotiations with the Army. With the Army's insistent voice in his ears, Compton, who had attended the conference, decided to break the rules and take Mr. Greenewalt to witness the first operation of a pile.

They all climbed on to the balcony at the north end of the squash court; all, except the three boys perched on top of the pile and except a young physicist, George Weil, who stood alone on the floor by a cadmium rod that he was to pull out of the pile when so instructed.

And so the show began.

There was utter silence in the audience, and only Fermi spoke. His grey eyes betrayed his intense thinking, and his hands moved along with his thoughts.

"The pile is not performing now because inside it there are rods of cadmium which absorb neutrons. One single rod is sufficient to prevent a chain reaction. So our first step will be to pull out of the pile all control rods but the one that George Weil will man." As he spoke others acted. Each chore had been assigned in advance and rehearsed. So Fermi went on speaking, and his hands pointed out the things he mentioned.

"This rod, that we have pulled out with the others, is automatically controlled. Should the intensity of the reaction become greater than a pre-set limit, this rod would go back inside the pile by itself.

"Presently we shall begin our experiment. George will pull out his rod a little at a time. We shall take measurements and verify that the pile will keep on acting as we have calculated.

"Weil will first set the rod at 13 feet. This means that 13 feet of the rod will still be inside the pile. The counters will click faster and the pen will move up to this point, and then its trace will level off. Go ahead, George!"

* * *

The experiment proceeded by small steps [with a break for lunch] until it was 3.20 p.m.

Once more Fermi said to Weil:

"Pull it out another foot"; but this time he added, turning to the anxious group in the balcony: "This will do it. Now the pile will chain-react."

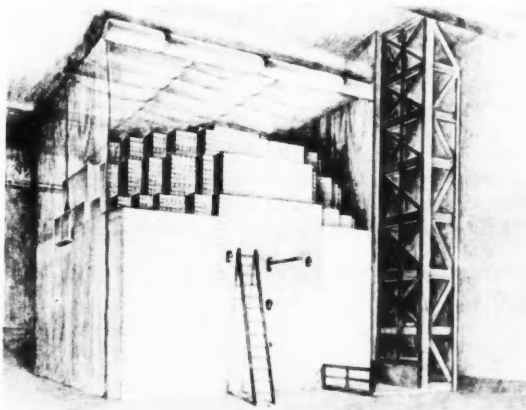
The counters stepped up; the pen started its upward rise. It showed no tendency to level off. A chain reaction was taking place in the pile.

In the back of everyone's mind was one unavoidable question.

"When do we become scared?"

Under the ceiling of the balloon the suicide squad was alert, ready with their cadmium liquid: this was the moment. But nothing much happened. The group watched the recording instruments for twenty-eight minutes. The pile behaved as it should, as they all had hoped it would, as they had feared it would not.

The rest of the story is well known. Eugene Wigner, the Hungarian-born physicist who in 1939 with Szilard and Einstein had alerted President Roosevelt to the



Sketch of the first atomic pile, with which Fermi and his colleagues achieved the first self-sustaining chain reaction in history on December 2, 1942.

importance of uranium fission, presented Fermi with a bottle of Chianti. According to an improbable legend, Wigner had concealed the bottle behind his back during the entire experiment.

All those present drank. From paper cups, in silence, with no toast. Then all signed the straw cover on the bottle of Chianti. It is the only record of the persons in the squash court on that day.

The group broke up. Some stayed to round up their measurements and put in order the data gathered from their instruments. Others went to duties elsewhere. Mr. Greenewalt hastened to the room where his colleagues were still in conference with the military. He announced, all in one breath, that Yes, it would be quite all right for their company to go along with the Army's request and start to build piles. Piles were wonderful objects that performed with the precision of a Swiss watch, and, provided that the advice of such competent scientists as Fermi and his group were available, the du Pont company was certainly taking no undue risk.

Arthur Compton placed a long-distance call to Mr. Conant of the Office of Scientific Research and Development at Harvard.

"The Italian Navigator has reached the New World," said Compton as soon as he got Conant on the line.

"And how did he find the natives?"

"Very friendly."

Here the official story ends, but there is a sequel to it, which started on that same afternoon when a young physicist, Al Wattemberg, picked up the empty Chianti bottle from which all had drunk. With the signatures on its cover, it would make a nice souvenir. In subsequent years Al Wattemberg did his share of travelling, like any other physicist, and the bottle followed him. When big celebrations for the pile's tenth anniversary were planned at the University of Chicago, the bottle and Al Wattemberg were both in Cambridge, Massachusetts. Both, Al promised, would be in Chicago on December 2.

It so happened, however, that a little Wattemberg decided to come into this world at about that time, and Al could not attend the celebrations. So he shipped his bottle, and, because he wanted to make doubly sure that it would not be broken, he insured it for a thousand dollars. It is not often that an empty bottle is considered worth so much money, and newspaper men on the lookout for sensation gave the story a prominent position in the Press.

LOS ALAMOS AND THE FIRST ATOMIC BOMB

[*One chapter of the book is entitled "Site Y". Site X was the code name of Oak Ridge, where U235 was concentrated by the gaseous diffusion process, while big piles for the production of plutonium had been built at Hanford. Site Y was where the scientists were to study all the problems connected with the design and construction of the atomic bomb: in Britain this has always been known as the Los Alamos Laboratory.*]

On August 13, 1942, a special district was formed in the Army Corps of Engineers to carry out atomic work. Its name, "Manhattan District", was intended to conceal all connexion with atomic research. On the following September 17, Secretary of War Henry L. Stimson placed Brigadier-General Leslie R. Groves in charge of the Manhattan District. It was decided at the same time that work should be greatly expanded as soon and as fast as possible. General Groves set himself to his task. He planned work on the atomic bomb even before the pile experiment on December 2, 1942, had definitely proved that release of atomic energy was feasible. He chose sites for new laboratories and production plants.

Study of all problems related to design and construction of an atomic bomb, the most secret part of the project, had to be furthered in a spot even more secluded than the other two.

In the search for such a place General Groves was helped by Prof. Robert Oppenheimer, or "Oppie", as his friends called him. Oppie's family owned a ranch in the Pecos Valley, on the eastern side of the Sangre de Cristo Mountains. Oppie was thoroughly acquainted with New Mexico. He suggested to General Groves a small boys' school on a lonely mesa by the Los Alamos Canyon, on the slopes of the Jémez hills.

The mesa by the Los Alamos Canyon was undoubtedly a secluded spot. The school buildings could accommodate the first scientists during the phase of construction. There was no danger of running out of space for expansion, for proving grounds, for erecting large machinery: as far as the eye could see, there were only pines and sand.

* * *

General Groves and Oppie went to see the school. The school principal must have been surprised by the strangely assorted pair: a slender intellectual with rounded shoulders and narrowed eyes, who acted as a guide to a burly Army officer, straight, direct of manner, with authority in his voice. The principal must have been even more surprised at his visitors' requests. The school must be closed. The Army wished to buy it for secret work.

The Manhattan District purchased the school in November 1942. Oppie was to direct the future laboratories, and General Groves asked him how many houses would be needed. Oppie expected to gather some thirty scientists and their families, perhaps a hundred persons in all.

Oppie turned out to be a marvellous director, the real soul of the project. In his quiet, unobtrusive way, he kept informed about everything and in touch with everyone. His profound understanding of all phases

of research—experimental, theoretical, technical—permitted him to co-ordinate them into a coherent whole and to accelerate the work. He carried the burden of his responsibilities with an enthusiasm and a zeal bordering on religiosity. But in predicting the size of Site Y he did not do so well.

The Special Engineer Detachment started construction in January 1943. They built homes. They built laboratories following vague directives of scientists who could not explain the kind of work they would pursue in them. Thus a city grew at 7200 feet above sea-level.

Into that city went scientists from all parts of the United States and England, to disappear from the world. For two and a half years the city was not marked on the maps, had no official status, was not part of New Mexico, its residents could not vote. It did not exist. That city was Los Alamos to those living there, Site Y to the few outsiders who knew about its existence, Post Office Box 1663 to correspondents and friends of the inhabitants.

The influx of new families on the mesa never ceased, and building went on at a feverish pace, invariably lagging behind the increase in population. At the end of the war, when the first statistics were published, the Los Alamos population was 6000. Ten years after its birth Los Alamos had 12,000 residents and a housing shortage.

When we arrived in Los Alamos, in August 1944, we found the confusion and the disorder that always accompany a fast pace of construction. Around the few original houses of the school, barrack-like buildings seemed to have been scattered at random. They stood at strange angles on streets without names that loafed aimlessly about the mesa and drew intricate patterns over it. The buildings were all alike, all painted green, inconspicuous among green pines, against the green background of the hills. One easily got lost in the uniformity of the houses and the intricacy of the streets with no names, but one could regain his orientation by the single landmark, the tall water tower on the highest part of town.

Long afterwards I recognised a logical design in the layout of houses: they were set diagonally to the streets, to utilise the ground best, leaving, however, sufficient space between them to keep fire hazards low. All houses were made of wood.

The old school house at Los Alamos which the atomic scientists nicknamed "The Big House".
(*Photo by O. R. Frisch*)

Buildings under construction emerged from thick seas of mud. There is never much protective vegetation on a high mesa, and even the little there is dies out when construction is under way. During the rainy season in the summer, the downpours turned the clay of the soil into slippery glue that stuck to the shoes and then hardened into heavy soles. When winter came, the snow, melting under the balmy rays of the midday sun, again turned the soil into mud. Construction materials and felled trees were piled along the sides of rutted roads where bulldozers, cranes and trucks sped blindly away as if they were the masters of the place.

Along the Los Alamos Canyon a strip of mesa was fenced off with chicken wire. Behind it was the Technical Area, where only persons with special badges could gain admittance. The main town entrance, the East Gate, led into the desert to Española and Santa Fe. Through the West Gate, open to civilians during certain hours only, one reached the mountain country, the fishing streams, the ski slopes, and the woods—woods of blue spruce, of Ponderosa pines, and of the aspens that turn yellow in the fall and cover the hills with foils of gold.

THE ALAMOGORDO TEST AND THE AFTERMATH OF HIROSHIMA

[*Not until August 7, 1945, did Laura Fermi realise that all the work of her husband and the other scientists she knew at Los Alamos (such as Bruno Rossi, Hans Bethe, Emilio Segré, Edward Teller, Rudolf Peierls and "Uncle Nick"—better known as Niels Bohr) was directed to the production of atomic bombs. After hearing the news of the Hiroshima explosion over the radio, she recalled the mysterious test—with the code name "Trinity"—which was in fact the first atomic explosion in all history.*]

"We repeat President Truman's words . . ." the announcer said, ". . . the first atomic bomb . . . equal to 20,000 tons of TNT. . . ."

How stupid of me not to have guessed! I had had my hints in the past. In 1939 I had heard that a chain reaction was theoretically possible. In 1941 a physicist's wife had given me Harold Nicolson's book that told of an imaginary diplomatic incident caused by the dropping of an atomic bomb. In 1943 Emilio Segré, on a visit to Chicago, had cheerfully greeted me with the cryptic assertion: "Don't be afraid of becoming a widow. If Enrico blows up, you'll blow up too."

Two of the outstanding personalities at Los Alamos were Prof. Niels Bohr and Dr. Oppenheimer. (*Photo by O. R. Frisch*)

I might have guessed, at least after the Trinity test, I thought to myself. On the other hand, I had heard very little about it. Early in July men had started to disappear from the mesa and the word "Trinity" had floated with insistence in the air. My boss, Dr. Hempelmann, had also gone to Trinity. By July 15 nobody who was anybody was left in Los Alamos, wives excepted, of course.

On the next morning word spread through the usual grapevine that a sleepless patient at the hospital in Los Alamos had seen a strange light in the early morning hours. The test, it was thought, must have gone off successfully. Late that evening some of the men returned. They looked dried out, shrunken. They had baked in the roasting heat of the southern desert, and they were dead tired.

Enrico was so sleepy he went to bed without a word. On the following morning all he had to say to the family was that for the first time in his life on coming back from Trinity he had felt it was not safe for him to drive.

A New Mexico paper mentioned the extraordinarily brilliant flash of light—perhaps a dump of ammunition had blown up, it said. Even a blind girl had seen it.

I had heard no more about Trinity. Men had resumed their work at the usual fast pace.

On July 16 at Alamogordo (called "Trinity" for security reasons), in the southern part of New Mexico, the first atomic bomb ever made had been exploded. General Farrell, in a report to the War Department released to the Press on the day after Hiroshima, used these words to describe the explosion:

"The whole country was lighted by a searching light with the intensity many times that of the midday sun. It was golden, purple, violet, grey and blue. It lighted every peak, crevasse and ridge of the nearby mountain range with a clarity and beauty that cannot be described. . . . Thirty seconds after the explosion came first the air blast, pressing hard against the people and things; to be followed almost immediately by the strong, sustained, awesome roar which warned of doomsday. . . ."

Now I could ask questions of Enrico. How would he describe the explosion? He would not be able to do it objectively, he said. He had seen the light, but he had not heard the sound.

"Not heard? How is it possible?" I asked bewildered.

All his attention, Enrico answered, was concentrated on dropping small pieces of paper. He watched them fall. As he had expected, when the air blast following the explosion hit them, it dragged them along. They fell to the ground some distance away from Enrico. He paced that distance counting his steps. He thus measured the path travelled by his bits of paper, and from it he was able to calculate the power of the explosion. His figures coincided with those of precision instruments and of accurate calculations. Enrico has always favoured simple experiments. He was so profoundly and totally absorbed in his bits of paper that he was not aware of the tremendous noise, described by other witnesses as "a mighty thunder" and "the blast from thousands of block-busters".

After he had completed his calculations, Enrico climbed on a Sherman tank lined with lead to screen the inside from radiation, and he explored the crater that the bomb had dug in the desert. A depressed area 400 yards in radius was glazed with a green, glass-like substance, the sand that had melted and then solidified again.

* * *

I was not prepared for the change that the explosion at Hiroshima brought about in our husbands at Los Alamos. I had never heard them mention that atomic bomb, and now they talked of nothing else. So far they had focused all their attention on their research, and now the entire world was their concern. To me they had seemed to be working with their usual zeal and dedication, and now they assumed for themselves the responsibility for Hiroshima and Nagasaki, for the evils that atomic power might cause anywhere, at any time.

As the papers published descriptions of destruction in Hiroshima in greater and greater detail, the men in Los Alamos asked themselves whether they could truly delegate all moral responsibility to the Government and to the Army.

To moral questions there are no universal answers. The range of reactions among our husbands was wide. Some felt that a rapidly ending war more than compensated for the destruction at Hiroshima and Nagasaki. Some told themselves that evil lies in the will to wage wars, not in discovery of new weapons. Some men said the atomic bomb should never have been built; researchers should have stopped working when they had realised that the bomb was feasible. Enrico did not think this would have been a sensible solution. It is no good trying to stop knowledge from going forward. Whatever Nature has in store for mankind, unpleasant as it may be, men must accept, for ignorance is never better than knowledge. Besides, if they had not built an atomic bomb, if they had destroyed all the data they

had found and collected, others would come in the near future who in their quest for truth would proceed on the same path and rediscover what had been obliterated. Then in whose hands would the atomic bomb be placed? Worse evils could be conceived than giving it to the Americans.

Among the scientists in Los Alamos the sense of guilt may have been felt more or less deeply, more or less consciously. It was there, undeniably. But it did not cause demoralisation, it caused hope.

These atomic bombs are too destructive, men said in Los Alamos after Hiroshima. They will not be used again. There will be no more wars. The atomic era must and will be an era of international co-operation, in sharing the benefits of atomic power for peaceful uses, in banning atomic weapons. There must be an international controlling agency and a system of inspection of atomic research and of atomic industry. Such a system presupposes mutual trust between the nations, and mutual trust will bring world government. Once this is attained, there will be no more fear of war. Everlasting peace, the dream of sociologists and pacifists, will have come true.

What country, they went on arguing, would refuse to go along with such a programme? What country could prefer utter destruction to survival? We, the most civilised nation, shall take the lead, show goodwill and confidence in the others; then they will follow us, they will open their doors to the international controlling body, they will relinquish their sovereignty to world government.

In October 1945, scientists who thought along these lines formed the Association of Los Alamos Scientists (which on the following January merged with other similar groups into the Federation of American Scientists). Their central policy, stated in a newsletter, was to "urge and in every way sponsor the initiation of international discussion leading to a world authority in which would be vested the control of nuclear energy".

Prompted by a crusading spirit, members of the Association of Los Alamos Scientists sought opportunities to bring their views to the public, to promote public understanding and free exchange of ideas between themselves and laymen. They drafted statements, they wrote articles, they gave speeches.

Enrico did not share many of these views. He used to say that historical precedent, for what it is worth, does not show that improvement of weapons frightens men into not waging war. He also thought that the harshness of a war is not so much determined by the technical advance of the means of destruction but is rather controlled by the will to use the weapons and by the amount of punishment the fighting countries are willing to take. Enrico did not think that in 1945 mankind was ripe for world government. For these reasons he did not join the Association of Los Alamos Scientists.

CARL FREDERIC GAUSS (1777–1855)

R. G. ROSE, B.Sc.

"The incomparable three", Archimedes, Newton and Gauss, are classed as the world's three greatest mathematicians. About Gauss, relatively little has been written in the English language. The unit of magnetic induction which bears his name usually provides the first introduction students of physics and mathematics have to his life and work.

Not only is a knowledge of advanced mathematics necessary to full understanding of Gauss's achievements, but his work also needs to be considered against the background of progress in mathematics up to the 18th century.

His contemporaries, particularly of the French school, immediately saw the significance of his masterpiece, "Disquisitiones arithmeticae" (1801). This document, together with his earlier Helmstedt thesis (1799), which collated his own and previous discoveries in number theory, are considered to be his greatest work. These publications may be regarded as the culmination of the period in which Gauss interested himself exclusively in the study of number theory.

It is possible to divide roughly the remainder of his work into the following periods: 1800–20, astronomy; 1820–30, geodesy and the theory of surfaces; 1830–40, mathematical physics—embracing electromagnetic theory, terrestrial magnetism and the theory of attraction according to Newton's Law; 1840–55, analysis situs and the geometry associated with the functions of a complex variable. The periods are in no sense rigid; there was overlapping, but they do give a guide to the time when these particular topics were uppermost in his mind.

Full discussion of Gauss's discoveries during these periods would require a book, but a brief consideration of some of his outstanding papers suffices to show the wide range of his original thought.

"Thesis motus corporum coelestium" (1809) was the outcome of his study of the newly-discovered planetoid "Ceres", soon after his interest in secular perturbations of planets had been aroused. Further studies appeared on the attraction of general ellipsoids, mechanical quadrature and a discussion of the hypergeometric series.

His theory of the method of least squares was applied to triangulation measurements and one result of this interest in geodesy was his surface theory, published in "Disquisitiones circa superficies curvas" (1827). His interest in pure mathematics still continued; for example with a treatise on complex numbers he was able to clarify some of his findings in number theory.

In conjunction with his younger colleague, Weber, he

Carl Frederic Gauss.

carried out much experimental work on terrestrial magnetism and invented, among other things, the bifilar magnetometer and the electric telegraph. To this period belongs his "Allgemeine Lehrsätze" (1840), the beginning of potential theory and the study of certain minimal principles of space integrals. During this period, he was attempting to derive a unifying theory of electromagnetic phenomena, but considered his results unsatisfactory.

Although other mathematicians had previously obtained some of the same results, Gauss dealt with fundamentals. It was in the light of Gauss's basic concepts that the results of previous workers in the same field found their explanation.

In 1798, Gauss visited the mathematical library of the University of Helmstedt. He wished to determine the state of higher arithmetic and also to discover those points in his "Disquisitiones arithmeticae" which had already been covered by others. Where the facts demanded it he was always willing to acknowledge the work of previous investigators. With his later works, however, this was not always possible as a number of relevant papers were generally unknown at the time. It may be noted that he did not publish the results of all his researches, and although priority of publication on a number of theories belongs to later mathematicians, it is known that he had earlier discovered elliptic functions and was fully aware of a geometry other than Euclidian.

Historians are agreed on the main facts of his private life, but with Gauss as with many other distinguished men some of the stories, probably factual in origin, have lost nothing in the telling over the years.

He was born in Brunswick on April 30, 1777. The suggestion that he should be educated beyond his classmates was opposed by his father. Encouraged by his mother, however, and helped by friends, he made exceptionally rapid progress in his studies.

He was fourteen years old when the Duke of Brunswick learned of his outstanding ability. The duke was favourably impressed when he interviewed him, and consented to finance Gauss's education. Later the duke offered him a pension. At the Caroline College, Gauss mastered not only mathematics, but the classics as well. He entered Göttingen University in 1795. For a while he hesitated in his choice of study. Philology in particular attracted him, but finally he decided to make the study of mathematics his life's work. After he had made this decision came the three most prolific years of his career. The "Disquisitiones arithmeticae" was almost completed at the end of this period, but was not published until he had been to the University of Helmstedt. While in Helmstedt, Gauss became a close friend of Pfaff, who was the acknowledged leader of mathematical thought in Germany.

Gauss returned to Brunswick in 1798, but on the death of his patron in 1806 he had to seek a livelihood to support his family. When these circumstances became known, he was immediately invited to fill the post of Astronomer to the Academy of Science and the Director of the Observatory in St. Petersburg. However, influential friends, anxious that he should remain in Germany, made it possible for him to be appointed to the Directorship of the Göttingen Observatory. Gauss accepted the post in 1807 and remained there until his death in 1855.

His published works did not reveal the full scope of his investigations. This was brought to light after his death, when others had access to his private journal and correspondence with his contemporaries.

Gauss's work and achievements did not go unrecognised in his lifetime. A greater willingness to publish his findings would undoubtedly have secured for him a wider fame and an even greater recognition. Two of the honours that were conferred upon him may be mentioned; there was his election as a foreign honorary member of the St. Petersburg Academy, and his appointment as a *Correspondant* to the French Academy.

He lived during one of the more tempestuous periods of European history. His discoveries in his own realm were as epoch-making as the Napoleonic upheavals in the political sphere. His work was largely responsible for breaking the long-established custom of treating mathematics as a means to an end for mechanics and astronomy.

(The portrait on this page is reproduced by courtesy of "Scripta Mathematica".)

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THE OBSERVATORY ON BEN NEVIS

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If you have been to Fort William and walked into Glen Nevis, you will have seen the path that winds up the hillside from the farm of Achintee. Perhaps you have toiled up this path to the top of Ben Nevis to the squat ruin of what was once a well-known weather station—Britain's only mountain observatory.

The idea of building an observatory here was conceived by an enthusiastic band of amateurs—members of the Scottish Meteorological Society. In 1877, the Council of this society obtained permission from the owner of Ben Nevis to establish a station on the summit. The secretary was Thomas Stevenson—lighthouse engineer, and father of Robert Louis Stevenson. It was he who designed the white-painted wooden box for shielding and ventilating thermometers, known as the Stevenson screen.

Thomas Stevenson was asked to prepare plans for this station. While these plans were going ahead, a Mr. Clement L. Wragge wrote to the secretary offering to climb the Ben daily during the summer of 1881 to make observations. His offer was accepted, and Stevenson designed a wire cage to enclose the instruments. You can see it still, near the ruin.

Each morning at 4.40, Wragge set out from Banavie and climbed up the north side of Meall-an-t-Suidhe to its lochan and then by Carn Dearg to the summit which he reached at 9 o'clock. After an hour there, he came down by the same route and reached sea-level at 3.30 in the afternoon.

He made observations at various points *en route* as well as on the summit. Day after day, despite blizzards and gales, and often coated with rime or glazed with ice, he would struggle on to the summit at precisely 9 a.m. The wide publicity given to Wragge's exploits served to direct attention to the society's plan. At a General Meeting, Sir William Thomson, later Lord Kelvin, proposed "that this Meeting, recommend the Council at once to appeal to the British Public for funds wherewith to erect on Ben Nevis a permanent observatory". The appeal was launched early in 1883, and in a few months over £4000 was subscribed.

A start was made with the construction of a bridle path, and masons began dressing granite blocks on the summit; the building was to be made out of the mountain. The original building consisted of one room, 13 feet square, from which three small sleeping bunks were entered. The walls were 12 feet thick at their base, and the inside had a double lining of wood covered with felt. The operation was conducted at a speed that present-day builders would deem indecent; indeed the observatory was built in four months and was formally opened on October 17, 1883. An armoured telegraph cable was laid from Fort William to the Observatory. You can still see it, if you make the uncomfortably rough bee-line down the Ben over Keats's "craggy stones".

The station's superintendent, Mr. Omond, and his two assistants began observations almost immediately. Wragge's work had shown that self-recording instruments could not be used because of heavy deposits of rime and frequent gales, so hourly observations had to be made by the observers. Almost at once, they encountered severe difficulties. As soon as snow began to lie to a depth of a foot or so, strong winds caused drifts to form round and over the building. The observer had to tunnel his way out to reach the thermometer screen. The tunnel grew to a length of over 30 feet with a rise in level of 12 feet to the snow surface. Whenever the wind rose, the tunnel was choked with snow and observations were interrupted. And you can imagine the inconvenience of having to cook, eat and wash as well as do the office and telegraph work in one small room. So, in the summer of 1884, other rooms were added and a 30 feet high wooden tower built to provide an exit in winter when the main door was blocked. In 1890, an observatory at sea-level was built at Fort William for the purpose of examining vertical gradients of pressure and temperature. (The cost of this was met by a grant from the organisers of the successful Edinburgh International Exhibition of 1886.) In late winter and spring when the mountain observatory was completely buried in snow, from which only the chimney and tower projected, conditions indoors were quite cosy. But in early winter, before the blanket of snow had settled round them, the observers might have to endure rigours so severe that even sleep was impossible.

Cloud lay over the summit on the average for two hours in every three. The cloud droplets were often super-cooled—that is, their temperature was below freezing, though they still remained liquid water. If the wind blew them against a solid object, they immediately froze on to it. So heavy deposits of rime grew out to windward from everything projecting from the summit. It choked the ventilators of the Stevenson screen and locked the wind recorder.

The standard exposure of a Stevenson screen is at a height of 4 feet above the ground—so the screens had to be placed on ladder-like stands and raised to the correct height as the snow level rose. In strong winds, the observer had to be roped and had to crawl to the screen. In severe gales, it was impossible to reach the screen and, to add to the hazards, lumps of ice and stones were hurled across the summit. Observations were then obtained from thermometers in an emergency screen attached to the outside wall. The thermometers, with stems projecting through the wall, could be read indoors. This was also used when overhead thunderstorms made it dangerous for an observer to venture out of doors. In thundery conditions all projecting objects—including the hair of the observers!—hissed and glowed with St. Elmo's fire. This happened so frequently that it was apparently accepted as a normal

A British high-altitude station could play a role as important in modern research as did the Ben Nevis observatory (seen here from the west) before its closure.
(*Courtesy the Editors of "Weather"*)

occurrence, but occasionally it heralded something more alarming—a lightning flash striking the summit. If that happened, wires to the telegraph instrument might fuse and small fires start in the walls—but damage was never serious, and though the observers suffered occasional shocks, no one was injured. Still, the approach of a thunderstorm must have been regarded with some apprehension. It is recorded in the log that "*cook left day after thunderstorm*", but cooks appeared to come and go at high frequency. The chimney of the stove, projecting from an exposed summit, formed an excellent lightning conductor, so cooking must have been an exciting business.

—Sometimes the chimney became blocked with ice, or simply "blew down", driving the observers outside. Their comments in homely language are recorded in the log. The entries in it give some idea of the hazards of the work. Here are a few of them:

"*As soon as Mr. Omond went outside door, he was lifted off his feet, and blown backwards against Mr. Rankin who was knocked over. Solid blocks of ice flying about. No observations possible for two hours.*"

"*Bright flashes of lightning! A flash from the stove struck Mr. Miller who was sitting at the desk in the office. The shock passed from his neck downwards but did him no injury.*"

"*Jets of St. Elmo's Fire four inches long from every point on top of tower and kitchen chimney. Fizzing noise from jets very distinct. While standing on the office roof watching the display, the observer felt an electric sensation at his temples and was told by the assistant that his hair was glowing.*"

Despite hardships and isolation, the observers came to like living on the summit, and often were reluctant to come down to do their spell of duty at the sea-level observatory—perhaps because they knew that their return to sea-level meant almost certainly the start of a heavy cold.

The cost of maintaining the two observatories was a continual worry to the society's management committee. A quite small annual grant was received from the State, and time and again only the generosity of wealthy members of the society kept things going. When part of the State grant was discontinued, questions in Parliament led to the appointment of a Government Committee of Inquiry.

Conflicting opinions were expressed by eminent scientists called before the Committee. Lord Kelvin held that: "The Ben Nevis observations are of the highest utility in the development of meteorology and in framing forecasts of storms and weather." Sir Arthur Schuster's view was that "the problems which could with convenience be examined at Ben Nevis have been dealt with". The outcome was an offer by the Treasury to restore the grant to its former, quite inadequate amount. The directors had no option but to close the observatory. The last entry in the log for October 1, 1904 is terse and formal. "This forenoon snow was falling and mist enveloped the summit. By command of the Directors, observations were discontinued at this observatory after the noon readings were recorded." And so after twenty-one years of hourly observations made night and day, from 1883 to 1904, the observatory on Ben Nevis was closed.

The scheme of work of the observatories had been planned by the distinguished meteorologist, Dr. Buchan, who was the professional secretary of the society for forty-seven years. To quote his words, the main purposes of the observatories were "first, to give warning of the approach of storms from the Atlantic and secondly, by the singular advantage that a sea-level observatory exists as near as four miles in horizontal distance, to investigate vertical gradients of pressure, temperature and humidity".

Of course, now that weather ships in the Atlantic give warning of the approach of storms and balloon-borne instruments provide regular observations of the upper air, the case for a mountain weather observatory is debatable. But there can be little doubt that had Ben Nevis Observatory been kept in working order, it would have been regularly used as a mountain laboratory for experiments on, say, radar, cosmic rays, icing and de-icing of aircraft and cold weather tests of aero-engines.

The complete records of the two observatories appear in the *Transactions of the Royal Society of Edinburgh* along with papers analysing the data and extracts from the log. Unfortunately, Dr. Buchan died in 1907 before he completed the ambitious programme of analyses that he planned. The Director of the Meteorological Office at that time, Sir Napier Shaw, with whom Dr. Buchan had to negotiate on the delicate matter of the State grant, wrote this in a memorial notice of Dr. Buchan: "We had to face so often and in such various ways, the question 'Is it any use?' The real question is 'Does the work stimulate that devotion to the extension of knowledge and the widening of our horizons, which are always the characteristics of scientific work?' If it does, utility will manifest itself in more ways than one." Shaw, at this time, could hardly have realised how prophetic were his words. Here's what happened.

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In the autumn of 1894, Prof. C. T. R. Wilson—now eighty-six years old and living near Edinburgh—spent a fortnight on Ben Nevis taking the place of one of the observers who was on holiday. He tells how, when he stood at the edge of the precipice overlooking the great corrie, he would see his shadow cast on wisps of cloud a few feet below him. And surrounding his shadow were brilliantly coloured rings of light—what's called, for obvious reasons, a "glory". Wilson was so impressed by these glories, that he resolved to study them when he returned to the Cavendish Laboratory at Cambridge, where he was then a research student. In order to imitate them in the laboratory, he produced a cloud by suddenly expanding, and so cooling, moist air in a vessel. But immediately, he came across something much more interesting than the optical phenomena he had intended to study. Out of these experiments came what is now universally known as the "Wilson Cloud Chamber", which has played, and is still playing a vital part in the development of nuclear physics and cosmic ray physics. But this was not all. His experiments on condensation also led him to make tests to find if the atmosphere was electrically conducting. There followed his monumental contributions to the subject of atmospheric electricity and the mechanism of thunderstorms.* And all this came from the observation of glories at Ben Nevis Observatory. Remember Napier Shaw's answer to the question. "Was it of any use?"

*In an article in *Weather* (October 1954, vol. 9, pp. 309–11) Prof. C. T. R. Wilson writes: "The whole of my scientific work undoubtedly developed from the experiments I was led to make by what I saw during my fortnight on Ben Nevis in September 1894." This article is illustrated by a remarkable photograph in Kodachrome of the Brocken Spectre from Tower Ridge, i.e. from the precise spot where Prof. Wilson made the observations that led eventually to the development of the Wilson cloud chamber. (The same number of *Weather* contains a full account with illustrations of the history of Ben Nevis Observatory, pp. 291–308.)

THE BOOKSHELF

The Inventor of the Valve

By J. T. MacGregor-Morris (*London, Television Society, 1954, 141 pp., 10s.*)

Prof. MacGregor-Morris's little book is evidently a labour of love and should be read as such, a clear and friendly testimony to his one-time chief Sir Ambrose Fleming, who invented the thermionic "valve" in 1904, received his first honour, the Hughes Medal of the Royal Society, in 1910, when he was 61, and lived to the abnormally ripe old age of 95.

The use of the word "valve" in the title is judicious. Edison first noted the blackening of the walls of a carbon-filament electric lamp and showed that a current flowed between the filament and a separate metal plate inside the same glass envelope. Fleming, then advisor to the Marconi Company as well as Professor of Electrical Engineering at University College, was the first to apply this effect to the rectification of high-frequency oscillations, and he accordingly applied for a patent for his device, aptly called a "valve". At first he called it an "oscillation" valve but afterwards a "thermionic" valve. It had two electrodes, a filament and a plate, and so was what we today call a diode. Every commercial radio receiver now uses a diode for its rectification stage.

This is by no means the only one of Fleming's claims to fame as an inventor and originator, to say nothing of his teaching; but it is the best known, and the author of this book has been wise to restrict his account of it to the background and facts of the invention and its patenting without going into the lifelong squabble with de Forest, who later, and apparently without any following-up of Fleming's work, invented the triode, the true basic tool of electronics. Prof. MacGregor-Morris has thus avoided giving the sort of embarrassment that was felt by at least one person at the recent celebration at the Institution of Electrical Engineers, when it seemed as if some had come to bury Fleming, not to praise him.

C. L. BOLTZ

Instrumental Methods of Chemical Analysis

By Galen W. Ewing (*New York and London, McGraw-Hill, 1954, 434 pp., 49s.*)

The author of this American textbook assumes that the student has taken an undergraduate course including quantitative analysis and a year of physics before reading this subject.

Part I describes twenty established instrumental methods of analysis, with the notable exception of distillation which the author considers is adequately dealt with in organic chemistry laboratory work. The underlying principles of each method are explained and the alternative types of instruments are described together with their mode of use. A set of revision questions and a short list of references to the literature is included under each heading. These sections are noteworthy for their lucidity and the excellence of the diagrams and charts.

Part II is devoted to a collection of thirty-three detailed experiments illustrative of the methods referred to in the earlier part.

This book provides a first-class introduction to this subject. D. S. HILL

Paper Chromatography

By Friedrich Cramer (trans. by L. Richard) (*London, Macmillan, 1954, 124 pp., 25s.*)

This book is intended primarily for use as a laboratory manual and appears now in translation from the second German edition. It shows how a new micro-analytical technique for qualitative work has been developed, and the way in which quantitative results to within 10% can be obtained by using spot extraction, retention analysis, photometry and autoradiography. The latter are briefly dealt with along with an introduction to paper electrophoresis.

A good feature of the book is the well-illustrated treatment of technical details such as equipment, solution strengths, and the choice of paper and solvents.

The way to run and develop chromatograms is described, and a transparent key is included for use as a reference.

Inevitably the treatment of biochemical materials is most detailed, particularly of amino acids and sugars, but other classes of compounds are adequately represented. The bibliography contains 362 references, giving a good survey up to midsummer 1952.

D. S. HILL

Elementary Chemical Engineering

By Max S. Peters (*New York, Toronto and London, McGraw-Hill, 1954, 322 pp., 46s. 6d.*)

This addition to the McGraw-Hill series on chemical engineering sets out to

cover the whole of the subject in an elementary fashion. Inevitably the treatment of the many branches is uneven and, though only a basic knowledge of mathematics, physics and chemistry is expected of the reader, many sections are hard to follow for someone who has not already a clear understanding of the subject. The arrangement of the text so that the chapter on industrial equipment precedes those in which the purpose of the equipment and the principles of its design are explained does not help the novice, and technical clichés follow one another with almost predictable regularity. It seems strange that so much of the limited space available in each chapter should be filled with a preamble in terms which positively invite précis.

All this should not, however, obscure the good features of the book. Many of the examples which follow each chapter are simple enough numerically to be solved without the use of a slide rule, while illustrating clearly the point they set out to make. In an appendix all the necessary physical data to solve these problems and much more besides can be found, which enhances the value of the volume for reference.

All in all this book suffers from attempting to cover too much ground without sacrificing either the theoretical or the practical aspects of chemical engineering.

Freshwater Microscopy

By W. J. Garnett (*London, Constable, 1953, 300 pp., 30s.*)

Those readers who know their Thurber will remember his piece in *My Life and Hard Times* called "University Days". In this he records that all too familiar experience—the failure to be able to see things through a microscope with the same clarity as the biology teacher or the textbook illustrator.

> "*Well*" [*the demonstrator*] *said to me*, "*we're going to see cells this time, aren't we.*"
>
> "*Yes, sir,*" *I said.*
>
> *Students to right of me and to left of me and in front of me were seeing cells; what's more, they were quietly drawing pictures of them in their notebooks. Of course, I didn't see anything.*

Of course, the chances are that Thurber's fellow students were busy doing what many before and since have done—copying out from a textbook some invisible (or only nebulously visible) objects which they were supposed to be able to see in full glorious detail. Textbook drawings are so definite, so sharp and so complete that comparatively few living microscopic organisms ever succeed in matching them, a discrepancy that can be most disconcerting to the tyro in the biology laboratory. It was many, many months before this reviewer ever saw a perfect textbook *Amoeba* under the microscope, and it is his conviction that previously he had drawn pictures of various blobby objects which may or may not have been *Amoeba*, insinuating into his drawings features which were not really visible but which ought to have been, assuming that the textbooks were correct. Moreover, it was not until he did one day spot an animal which was undoubtedly an *Amoeba* that he realised that he had previously been fooling himself—and his biology master—so completely as to render his notebook sketches quite valueless; obviously they had no more zoological significance than a picture of a unicorn. This kind of thing happens because students pin so much faith on textbook drawings. Many such illustrations are not pictures of living animals at all, but *diagrams* that compound all the details of structure which have been elucidated over a great many years by a great many observers.

For this reason a beginner may do better to refer to good photomicrographs rather than to rely solely on the drawings of idealised organisms such as are customary in textbooks. Photomicrographs are probably less likely to mislead the uninitiated; those of *Amoeba* which are reproduced in this new book would quite certainly help to bridge the gap between what a young biology student will actually see when he looks through a microscope and the textbook diagram of the same creature. A book of this type could do a lot of good if widely used by students, for it could establish a standard of honest observation which is essential for anyone who wants to do something more than just pass biology exams.

The author of this book is, of course, one of the Garnetts of the famous firm of Flatters and Garnett of Manchester. The book provides an excellent coverage of the microscopic organisms to be met with in fresh water. It deals with elementary matters of morphology most effectively, and as one would expect of an author who has studied microscopic pond life ever since he was a boy, he treats all the organisms he deals with as *living* organisms and gives many interesting details of their natural history.

The book begins with advice on the collection of specimens, and on microscopic equipment. The third chapter, entitled "Examining the catch", describes in some detail some of the tricks of the microscopist's trade. A bibliography provides a list of books on practical microscopy; one is just a little surprised to find that the author has omitted from his list Dr. R. Barer's *Lecture Notes on the Use of the Microscope* (1953).

The rest of the book concentrates on the commoner types of micro-organisms that live in fresh water. This is done systematically, the author starting with the algae, bacteria and fungi, and passing on to the protozoa, freshwater sponges, *Hydra*, planarians, nematodes, rotifers, polyzoa, mollusca, crustacea, water mites and insects. Those who want further details on the structure and natural history of freshwater organisms will find excellent lists of books for further reading; some of these books will solve problems of identification of specimens, and of classification.

Finally, there is a compact chapter on "Making permanent mounts", which certainly contains all the information which the beginner needs on this topic.

This is a first-class work, which the reviewer particularly recommends for its fine collection of photomicrographs; such pictures could do much to sow the seeds of honest observation among students who are embarking on a first course in biology. Amateur microscopists will also find this a useful book.

The English Climate

By C. E. P. Brooks (*London, English Universities Press, 1954, 214 pp., 12s. 6d.*)

In this book, which is written primarily for the layman, Dr. Brooks gives a simplified, non-technical account of a subject which provides an inexhaustible topic for conversation and uninformed argument. But despite its considerable human interest, climatology, in its present stage, can be a dull science—a subject of many facts, some fancies, but no physics! It is therefore a matter for congratulation that Dr. Brooks has been able to produce a readable, interesting, if not completely satisfying book. The reader is spared the usual mass of undigested statistics and given a factual account of the English climate, its effects and repercussions on human life and affairs. It does not pretend to be detailed, complete or profound, but sets out to trigger the layman's latent interest in his environment and offers him some useful advice.

The author begins by describing how Britain's geographical position, in relation to the large-scale features of the general circulation of the atmosphere and the oceans, largely determines her climate and weather. Then follows a description of the climatological distribution of winds and temperature in relation to the characteristics and trajectories of the air masses.

The third chapter headed "Storms and Squalls" is largely given to descriptions of particularly violent storms, squalls and tornadoes which have occurred in the past; this highlighting of rare, spectacular events, which is a recurrent feature of the book, will no doubt help to capture the general reader's imagination, but it hardly presents him with a well-balanced picture. Climatology should be concerned more with normal or average conditions and trends than with isolated and exceptional occurrences.

After the next two chapters (dealing with the frequency and distribution of rain, snow and hail, and of fog and atmospheric pollution), we come to the three chapters which will, perhaps, be of the greatest interest to the layman. The first deals with local climate on the scale of a small town or even an individual house, and how this is influenced by aspect, topography, terrain, vegetation, the presence of water, etc. The author then indicates how these factors should be taken into consideration when

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deciding where to live, to build a house, take a holiday or to retire. Unfortunately, these decisions have generally to be based on other than climatological grounds, but one must admire the way in which Dr. Brooks takes his own advice, for on p. 118 appears the following sentence: "The present author, when working in London, experimented with homes in various places, and finally settled down on the south coast." In a chapter entitled "Climate and Fitness", Dr. Brooks attempts to assess the importance of climate in maintaining the general level of health and capacity for sustained and fruitful work, either physical or mental, and concludes that the south coast of England is the most favourable region, the least favourable being the Western Isles of Scotland and the Manchester area. Many readers will, no doubt, be glad to learn that there is some evidence in favour of their nervous disorders, mental depressions, rheumatism and other aches and pains being correlated with the occurrence of cold fronts, thunderstorms, charged clouds, inversions, etc.; your reviewer remains highly sceptical.

In Chapters 9–13 the author discusses the occurrence of spells or singularities (i.e. periods of characteristic weather which *tend* to occur on or about the same dates in most years) and examines them in some detail as characteristics of the four seasons of the year—again with particular reference to notable historical events. Chapter 14 deals with cycles in various weather elements and points out that they are neither sufficiently regular nor persistent to be useful in long-range forecasting. Like singularities, they appear to be definite features of the atmospheric circulation, but their cause is still obscure. This is the province of dynamical climatology—still very much in its infancy; meanwhile statistical analysis of the observational data continues to pose the problems for ultimate solution by mathematical and physical methods.

In this book, which concludes with a rather sketchy description of the main features of the weather chart, Dr. Brooks attempts to persuade his readers that we live in a healthy and stimulating climate. Like many of our finest institutions, it may not be for export, but it suits us well enough!

B. J. MASON

A Treasury of Science

Edited by Harlow Shapley, Samuel Rapport and Helen Wright (*London Angus & Robertson, 3rd edn., 1954; 654 pp., 21s.*)

This is the third edition of an anthology of scientific writings selected from thousands of books and articles by many authors from many countries. The final result must have come after a prodigious effort on the part of the editors in reading, selecting and assembling the material to attempt an integrated work of this magnitude. This book is designed for the general reader, but it is so far-reaching in its final form that the professional scientist, who must by necessity today be a specialist in a particular field, will find in it much to enjoy and to interest him. For this new edition includes development in many of the modern branches of science, including nuclear physics, chemotherapy, plastics. It also shows the scientist at work and quotes from the writings of many of the world's greatest scientists, such as Galileo, Pasteur, Curie, Jeans.

The editors have selected their material under five main headings: Science and the Scientist, the Physical World, the World of Life, the World of Man and Science and the Future. This may not be the most topical method of presentation but it is a convenient manner of approach in a book which is intended for the general reader.

The final chapter is fascinating, and many readers will be engrossed in such subjects as Machines that Think, Space Flight and the Synthetic Industry. "Pictures of the past show log cabins, sailing frigates, oil lamps, caravans and prairie schooners. . . . Today life is mechanised, electrified, abundant. . . . In the future citizens will more effectively farm the land and the seas; obtain necessary minerals from the oceans; clothe themselves from coal and oil; keep themselves warm by using the stored energy of the sun; be cured of many ailments by a variety of drugs and medicinals; be happy, healthy and kittenish at 100 years of age; and perhaps attend interplanetary football matches in the Rose Bowl."

Naturally in such a large volume the quality of the writing varies, but on the whole the standard is high and the interest maintained. It is a book to be taken up and read at leisure, to be put down and picked up later when the mood demands. It is not an encyclopedia of scientific knowledge, but it should whet the appetite of many readers to delve further into many branches of science, and for this reason alone the editors will have achieved a very useful purpose.

Science and Freedom: The Proceedings of the Hamburg Conference

(*London, Martin Secker & Warburg, 295 pp., 21s.*)

This book has been compiled from a selection of the speeches and discussions which took place at Hamburg during four days at the end of July 1953. This International Conference, which was convened by the Congress for Cultural Freedom, was attended by over one hundred eminent scientists and scholars from nineteen countries. Among the subjects under review were the social organisation of research, the scientific method, scientific freedom, the philosophic foundation of free inquiry and State subsidies. The chairman of the committee responsible for organising the congress, Prof. Michael Polanyi, of the University of Manchester, states in the preface: "The historical turning point which forms the intellectual background of this Conference is the collapse of the Messianic ideal which has increasingly dominated European political thought since the birth of the idea of progress, about the middle of the 18th Century." The reconquest of freedom was then the main purpose of the Congress and this was presented under three general headings: (1) the suppression of intellectual freedom under totalitarian governments; (2) the reform and improvement in organisation of scientific activity in free countries; and (3) the clarification of the philosophical foundation of the idea of freedom in science.

In many of the subjects under discussion there was complete unanimity of opinion, for example, on the question of integrity of scholarship in relation to its dependency on public funds or the need of a positive system of education in the promotion of a genuine appreciation of freedom in science.

But there seems to have been less agreement among the speakers on philosophical grounds. Two main schools of thought appeared: one section saw in totalitarian government a revival of religious fanaticism, while the other stated categorically that universal scepticism had brought about 20th-century totalitarianism with its rejection of traditional beliefs leading to nihilism which in turn formed the philosophical background of the authoritarian State.

Here then is a book which will fascinate all who are interested in the philosophical aspects of science in the present position of scientific research in the community.

Drawings of British Plants. VII. Leguminosae

By Stella Ross-Craig (*G. Bell and Sons, London, 1954, 12s.*)

Some of the commonest and most attractive of our wild plants belong to the Leguminosae, the family illustrated by the seventy-six excellent plates now made available by the skill of Miss Ross-Craig. The drawings of the plants are delightful, and, because of the careful representation of detail, these plates will ease the sometimes perplexing task of naming the closely related species of *Lotus*, *Vicia*, *Trifolium* and *Lathyrus*. Maybe, one of these days, Miss Ross-Craig will be able to show us the plants in colour, and so add to her grace of line that crowning glory which colour alone can give.

One omission is puzzling: there is no plate of the starry clover (*Trifolium stellatum*), although other plants are figured which are known to be introductions to the British flora. There are doubtless good reasons for the omission, which is nevertheless notable, for the plant has occurred steadily in one locality since 1804, and is not unknown elsewhere.

B. BARNES

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BARNES

FAR AND NEAR

Atomic News

The Australian Atomic Energy Commission is building a nuclear reactor costing £A5,500,000, and this will be used primarily as a research tool. Data coming from its operation will be shared with Britain. This information was given to the first meeting of the Business Advisory Group of the Australian A.E.C. by MR. HOWARD BEALE (the Australian Supply Minister), speaking in Sydney on February 21. He told the meeting that Australia benefits from an arrangement with Britain that provides for a full exchange of knowledge on the industrial use of atomic power. He said this arrangement made available the knowledge gained from many years of research in England, costing hundreds of millions. It was of incalculable value. Australia would now be starting level with Britain, instead of from scratch, and therefore would be "away ahead of most other countries in the world". He spoke of Australia's special need to develop atomic power for industrial purposes. However, this did not mean that nuclear power plants would be built throughout the nation. Such power had attractive possibilities in areas like South Australia, where there was no hydro-electric power and very little coal. In States such as Victoria and N.S.W. nuclear power was not likely for at least twenty years. He expected Australia might build half a dozen such plants in the next twenty-five to fifty years.

* * *

By arrangement between the Australian Government and the U.K. Government certain tests relevant to atomic weapon development will take place in Australia later this year in an area north of the Transcontinental railway line.

These will not be atomic bomb explosions, but detonations of high explosive charges to test techniques relating to atomic weapons.

* * *

The second meeting of the Council of CERN (the European Organisation for Nuclear Research) took place in Geneva on February 24. One item on the agenda was "procedure over applications for membership". After discussion, the meeting passed the following resolution:

"According to Article III of the Convention, States not yet members of the Organisation can apply for membership. During the period of the building up of the Organisation the Council considers it advisable to defer action on such applications until January 1957. However, the Council authorises the Director-General to accept, prior to that date, subject to approval by Council and on appropriate terms, suitable research workers from non-Member Countries as collaborators in the work of CERN.

* * *

The General Electric Co. Ltd. announces that MR. R. N. MILLAR, lately Chief Mechanical Engineer to the British General Electric Co. (Pty.) Ltd., Australia, has been appointed to take charge of its newly formed Industrial Atomic Energy Section.

The new organisation is located at the company's Erith works which is under the direction of Mr. Arnold Lindley, and will develop designs of plant for the utilisation of atomic energy in power station generating equipment.

* * *

Dr. John C. Bugher, an expert in the medical effects of radioactivity, disclosed to the U.S. Senate armed services committee that during the Bikini atomic bomb test in 1954, in addition to Japanese fishermen, 300 Marshall islanders and task force personnel were injured by radiation, eighty-four of them being subjected to severe exposure.

The Geneva Conference on Atomic Energy

The United Nations Conference on the peaceful uses of atomic energy will open in Geneva on August 8, under the presidency of DR. HOMI BHABHA, chairman of India's Atomic Energy Commission. PROF. WALTER G. WHITMAN, head of the Department of Chemical Engineering at the Massachusetts Institute of Technology, will be Secretary-General of the conference, and he will be assisted by a three-man U.N. Working Party consisting of U.N. Under-Secretaries Ralph J. Bunche and Ilya S. Tchernychev, and Dr. Gunnar Randers, the Norwegian atomic scientist who was appointed in December as special consultant to Secretary-General, Dag Hammarskjold, in matters relating to the conference.

The extensive provisional technical agenda shows that after a keynote address by Dr. Bhabha, the conference will open by considering the world's estimated power requirements in some fifty years' time. This, it states, is necessary "in order to set the stage for discussion of the effect of nuclear energy on the world power problem".

The agenda is divided into the following main subjects: need for a new power source; the role of nuclear energy; the building of a nuclear energy enterprise; health and safety aspects of nuclear energy; production and use of isotopes; problems relating to large quantities of radioactive substances. All these will be considered in plenary session. In addition sectional meetings will be held on such topics as reactors, biological and medical questions, and the application of isotopes to research and industrial problems.

The N.Z. Heavy Water Plant

In our February 1955 issue (p. 50) we published a note about the plans for the heavy water plant to be built in New Zealand. It has since been announced that a company—Geothermal Development Ltd.—has been incorporated to run this joint U.K.-New Zealand enterprise. The sole shareholders are the N.Z. Government and Britain's Atomic Energy Authority.

This project for producing heavy water and electric power from geothermal steam has been under prolonged study by scientists and engineers in New Zealand and at Harwell, in collaboration with Merz and McLellan (consultants to the N.Z. Government on electric power) and Head Wrightson Processes Ltd. (consultants to A.E.R.E. on heavy water). In November 1954 a British mission including a number of scientists from Harwell visited New Zealand to discuss details.

The capital required for the heavy water plant (estimated at £2 million) will come from the Authority, and that for the electric power equipment from the N.Z. Government.

The board of directors comprises three representatives of the N.Z. Government; and two from the U.K. Atomic Energy Authority, namely Sir Donald Perrott and Mr. A. S. White, who is head of the Chemical Engineering Division at Harwell.

It is envisaged that production of heavy water will begin late in 1957 and of electric power a few months later. Initial plant will produce a useful tonnage of heavy water for nuclear power reactors, and the A.E.A. has undertaken to buy the whole of the output.

"Endeavour" Essay Prizes

Endeavour is again offering prizes totalling 100 guineas for essays on scientific subjects, including two special prizes for competitors who are eighteen or under on June 1, 1955. The subjects for this year are as follows:

1. The Earth's Magnetism.
2. Man-made Fibres.
3. Climatic Changes.
4. Scientific Aids to Food Supply.
5. Respiration.
6. New Metals for Engineers.

For the main prizes the age limit is twenty-five years (on June 1), the date by which entries must reach The Assistant Secretary, British Association for the Advancement of Science, Burlington House, Piccadilly, London, W.1. Essays must be in English and typewritten, and should not exceed 4000

words in length. Additional details can be obtained from the British Association.

Postgraduate Awards in Agricultural Research

The Agricultural Research Council has issued a useful booklet about the Training Grants, Research Studentships and Fellowships which the Council is offering in 1955. The booklet also gives information about the openings in the agricultural research and advisory services.

Two Veterinary Research Fellowships, valued at £850 per annum plus superannuation and tenable for three years, will be open to workers holding a veterinary qualification who have had not less than three years' experience in veterinary research, and three Junior Agricultural Research Fellowships, valued at £630 per annum plus superannuation, and also tenable for three years, will be open to honours graduates with not less than three years' postgraduate experience.

In addition, the Council is again offering up to thirty postgraduate Training Grants and Research Studentships in agricultural and veterinary science, applications for which should reach the Council without delay.

Further information and a free copy of the booklet can be obtained from the Secretary, Agricultural Research Council, Cunard Building, 15 Regent Street, London, S.W.1.

Chlorophyll Keeps Silver Bright

Chlorophyll, a familiar ingredient in various commercial preparations, for which remarkable absorbent properties are claimed, can prevent silver and copper articles from tarnishing. It absorbs hydrogen sulphide, traces of which in the air are responsible for tarnish. The Chemical Research Laboratory of DSIR has prepared wrappings of various sorts, impregnated with chlorophyll, which have kept silver and copper bright and shining in atmospheres containing a high proportion of hydrogen sulphide.

The Laboratory has been experimenting with a number of substances that might be used for impregnating wrappings for silver and copper and their alloys. Chlorophyll has proved to be one of the most successful. The wrappings used so far in the experiments have been made of paper. A weak solution of chlorophyll in oil or water and alcohol was sprayed on tissue paper, or the paper was dipped in the solution, and allowed to dry. Articles wrapped in this and sealed with sticky tape remained bright in contact with hydrogen sulphide. The concentration for the wraps was about 5% chlorophyll by weight. (For thicker wraps this concentration could be reduced.) It would be possible to use other materials, as long as they consisted mainly of cellulose. Strawboard, millboard and natural and artificial fibres, such as flax, hemp, jute and rayon come into this category.

Silver and copper articles do not need to be sealed hermetically to remain bright. For example, articles in jewellers' showcases could simply be laid on the chlorophyll paper, which will absorb the hydrogen sulphide in the atmosphere. This would also keep a canteen of cutlery in a home untarnished for a considerable time.

Dr. Pontecorvo in Russia

The mystery about the whereabouts of Dr. Bruno Pontecorvo, the Harwell scientist who vanished in 1950, was cleared up last month when the Russian newspapers *Pravda* and *Izvestia* both printed a letter by him. One passage in this reads as follows: "From the very first month of my stay in the Soviet Union I was offered various opportunities of working in the sphere of non-military use of atomic energy. At the Institute of Physics of the Academy of Sciences I was permitted to use in my research work a synchrocyclotron instrument." He described himself as a Stalin Prizewinner, which means that this award had been kept secret at the time it was made. Following the publication of this letter, one of his former colleagues at Harwell, Prof. H. W. B. Skinner of Liverpool, made a statement to the *Daily Express* (2.3.55), which refutes the idea that many Harwell secrets must have been taken to Russia by Dr. Pontecorvo. Prof. Skinner said, "Pontecorvo was never asked to take part in any military atomic work after the war. He had a most privileged position at Harwell. Though on the pay-roll of what was mainly a defence establishment, he was allowed to do cosmic ray research which had no foreseeable application to weapons or atomic power." The Atomic Energy Authority confirmed this statement, and their spokesman said that Pontecorvo's Harwell experiments have never been published—"not because they were secret but because they were unfinished".

Exposure of a Ten-millionth of a Second

A "camera"—more precisely, a "sequential image converter"—has been developed and constructed by a British firm, Winston Electronics Ltd., to enable photographs of one ten-millionth of a second exposure and at one half-millionth of a second intervals to be taken, six at a time. This is a frame-rate of two million per second. At least twenty-five times as fast as any other photographic method. One such instrument has just been flown to the U.S.A., where it will be used at the Aberdeen Proving Grounds, one of America's major rocket-testing centres.

Scientific Tests of New Open Fire

A report is published in the March 1955 issue of the *Journal of The Institute of Fuel*, giving the results of tests made to gauge the effect of a new type of appliance on domestic fuel consumption and comfort.

The tests (conducted in the Leatherhead area by a research team from the Domestic Appliances Laboratories of the British Coal Utilisation Research Association) took the form of a comparison between the ordinary open fire and a new type of appliance which has recently become commercially available, namely the free-standing open fire incorporating a reduced flue opening and chimney damper. These tests involved the co-operation of thirty-nine housewives, who weighed all the fuel put on their fires.

The results were striking. First, there was a fuel saving of 21% with the free-standing fires, despite the fact that they were used for longer periods. Secondly, it was clear both from the scientific measurements and from the comments of the users that the rooms in which the new fires were installed were much warmer and more comfortable. Their efficiency was computed to be 60–70% higher than that of the normal open fire.

A Blind-Deaf Aid

The Carnegie United Kingdom Trust has provided financial support for the development of a new machine to assist blind and deaf people. The inventor is Mr. A. R. Cooper, who is Controller of the North-West Region of the British Electricity Authority. By 1952 Mr. Cooper had made twelve pocket models of the machine consisting essentially of a typewriter keyboard controlling a set of six small studs or pins so arranged as to bring up under the finger of the reader the Braille notation of the letter pressed on the keyboard by the operator. The inventor has since made continuous progress in perfecting the mechanism and in adding to it a precision printing unit. Towards the close of 1954 a prototype had been produced. The machine, patented under the name "Arcaid", is now a little larger than pocket-size but still conveniently small. It incorporates a mechanism without levers, bearings or friction parts and has practically nothing that can go out of order or wear out. It can be used for touch-Braille as described above, or as a very efficient Braille printer. It is in the latter field that its principal use may lie for it will help not only the deaf-blind but also the blind, who will be able to receive private letters from social and medical workers and from friends who have access to machines. After a few final modifications a small number of models will be made and brought into use before production of larger numbers begins.

Night Sky in April

The Moon.—Full moon occurs on April 7d 06h 35m U.T., and new moon on April 22d 13h 06m. The following conjunctions with the moon take place:

April			
10d 03h	Saturn in conjunction with the moon	Saturn	6° N.
20d 05h	Venus ,,	Venus	7° S.
25d 02h	Mars ,,	Mars	0·7° S.
28d 02h	Jupiter ,,	Jupiter	3° N.

In addition to these conjunctions with the moon, Mars is in conjunction with Aldebaran on April 25d 23h, Mars being 6·4° N. of Aldebaran.

The Planets.—Mercury is in superior conjunction on April 23 and is unfavourably placed for observation throughout the month. Venus rises at 4h 40m, 4h 20m and 4h on April 1, 15 and 30, respectively, and can be seen for a short period before sunrise. The stellar magnitude of the planet varies from −3·5 to −3·4 and the visible portion of the illuminated disk from 0·756 to 0·835. Venus is receding from the earth, its distances on April 1 and 30 being 107 and 124 millions of miles, respectively.

Mars sets about 22h 30m during April and has an eastward motion in Taurus.

Jupiter is visible during the night and does not set before the early morning hours, at 2h 55m, 2h 05m and 1h 10m on April 1, 15 and 30, respectively. It is close to the moon on April 28 in the early morning, and in the third week of the month it lies a little S. of κ Geminorum. Its stellar magnitude varies from −1·8 to −1·6, the decrease in brightness being due to the increase in its distance from the earth.

Saturn rises at 22h, 21h and 20h on April 1, 15 and 30 respectively. Its retrograde motion in Libra may be detected by comparing its positions with γ Librae; at the end of the month it will be seen further W. of this star than it was at the start.

The Lyrid meteor shower attains a maximum about April 21, but is active for a few nights before and after this date.

DEUCE: English Electric's New Computer

The first demonstration of DEUCE, believed to be the most advanced electronic calculating machine in Europe, was given on February 17 at the Nelson Research Laboratories of The English Electric Company Limited, Stafford. The machine's name is an abbreviation of the full title—Digital Electronic Universal Calculating Engine.

The machine is the outcome of some years of intensive development of ideas first put forward soon after the war at the National Physical Laboratory at Teddington. NPL's director, Sir Charles Darwin, approached the firm with a request that it should assist his with the development of ACE (Automatic Computing Engine), a machine whose design had already been worked out at the NPL. The company provided a team of engineers and craftsmen to work at Teddington and, as a result, the pilot model ACE was brought into successful operation early in 1952. Experience gained with this machine was of tremendous help in determining the next stages of development and English Electric decided to produce a fully engineered version of this machine, embodying all the improvements suggested by the extensive operational experience gained at the National Physical Laboratory.

The new computer, which has an immediate access store of twelve mercury delay lines, also has a magnetic drum "memory" of a quarter of a million digits and can undertake division in one five-hundredth of a second and add at the rate of 64-millionths of a second. An example of the kind of work it can deal with very effectively is the solution of large sets of linear algebraic simultaneous equations, such as arise in connexion with engineering problems. The solution of a set of 60 such equations could never be contemplated using traditional desk computation methods. The total time required for solution on DEUCE, including the input of information and output of the solutions on punched cards is 18 minutes. The largest set of simultaneous equations which has been solved was a set of 115 equations with 37 right-hand sides. (DEUCE has already given rapid solutions of design problems associated with the P1 fighter plane, for instance.)

During 1956 six of these machines, each of which costs about £50,000, will be manufactured. One has been ordered by the National Physical Laboratory at Teddington, while another will go to the Royal Aircraft Establishment at Farnborough.

Two further DEUCE computers will be used by English Electric itself to initiate a computing service for industry at its Nelson Laboratories at Stafford and at Marconi House in London.

Personal Notes

The Institution of Mechanical Engineers have awarded the James Clayton prize for 1954 to SIR CHRISTOPHER HINTON for his pioneer work in applying the results of nuclear research to the production of fissile material and industrial power. Sir Christopher Hinton is Director, Industrial Group, of the Atomic Energy Authority.

The Royal Agricultural Society has awarded its 1955 gold medal to SIR JAMES SCOTT WATSON, for distinguished services to agriculture. Until his recent retirement Sir James was Chief Scientific and Agricultural Adviser to the Ministry of Agriculture.

DR. F. W. G. WHITE, Chief Executive Officer of Australia's CSIRO (equivalent to Britain's DSIR) has just visited Egypt to advise the Government on the organisation of scientific research. His visit was arranged under the aegis of the Unesco Technical Assistance Programme for Egypt, and lasted six weeks.

Sir Edward Bullard leaving N.P.L.

SIR EDWARD BULLARD is resigning from the directorship of the National Physical Laboratory, Teddington, which he has held since 1950. He returns to Cambridge University as a Fellow of Caius College, to undertake research into geophysics.

Book Catalogues

H. K. LEWIS & CO. LTD. (36 Gower Street, London, W.C.1) have just printed a new 36-page catalogue of books on Agriculture, Horticulture, Animal Husbandry and Veterinary Science. A short list of volumes on Fisheries is also included.

W. HEFFER & SONS LTD. (Petty Cury, Cambridge) have a new catalogue (No. 675) for those interested in the history of Science and Technology. This includes new books as well as collectors' items, among which one finds a copy of Fuchs' herbal of 1542, priced at £95.

Photographic Plates for Nuclear Research

Ilford Ltd. is today the largest producer of special photographic plates used for research purposes in nuclear physics, and the address of the company's chairman, the Hon. James P. Philipps, at the annual meeting contained an interesting illustration of the unusual character of some of these materials. He mentioned that the firm recently produced what was in effect a solid block of photographic emulsion 14½ inches by 10½ inches by 6 inches. This weighed over 1 cwt. and the value of the silver it contained was £300. This was sent up by balloon in Italy to an altitude of nearly 20 miles under a joint venture involving cosmic ray researchers of the University of Bristol and of several Italian universities. Also singled out for special mention in this address was the firm's HPS plate, described as the fastest photographic material in the world today. This plate first became available for the Coronation in 1953, and has made possible many news photographs that would otherwise have been lost to newspapers and magazines.

* * *

The use of photographic film for the measurement of radiation doses of x- and gamma-rays is the subject of a 28-page U.S. National Bureau of Standards Handbook, entitled *Photographic Dosimetry of X- and Gamma-Rays*, and written by Margarete Ehrlich. The data it presents are the results of an extensive programme in this field conducted over a number of years by the bureau's Radiation Physics Laboratory.

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